VOLUME 29 NUMBER 5

NEXT MONTHLY MEETING, JANUARY 14, 1908

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

MID-NOVEMBER 1907

NEW YORK MEETING, DECEMBER 3-6, 1907

MID-NOVEMBER 1907 VOL. 29 No. 5

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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1906-1907

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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 29 MID-NOVEMBER 1907 NUMBER 5

THE Twenty-eighth Annual Meeting of the Society will be held in the city of New York at 29 West 39th Street, December 3 to 6. This will be the first general meeting held in the new headquarters, consequently there will be the largest attendance in the Society's history and therefore the greatest opportunity for members to meet their friends.

An attractive program has been arranged by the Meetings Committee as shown on the following pages. Provision has been made for the holding of several sessions simultaneously, should the occasion require.

Many objects of engineering interest will be now available for visits for the first time, particularly the tunnels under the North and East Rivers.

The headquarters for all purposes will be in the foyer on the ground floor of the building and will be opened Tuesday December 3, at noon, and maintained throughout the meeting. As you enter, you are asked to register at once, so that you may receive your badge and program. Present your railroad certificates as early as possible for validation. The headquarters and general arrangements will be in charge of Mr. S. Edgar Whitaker (Badge No. 5) Office Manager.

The Secretary cannot undertake to reserve rooms for members or guests at the hotels. Members are invited to communicate direct with the hotel at which they desire to stop.

The Meetings Committee are in charge of the meetings, Mr. G. R. Henderson, chairman, Mr. A. E. Forstall, Mr. C. W. Baker, Mr. W. E. Hall, and Mr. L. R. Pomeroy. Mr. Charles R. Pratt is the chairman of the Reception Committee.

The officers of the Society and officials of the meeting will be designated by the following badge numbers.

No. 1	Prof. Frederick R. Hutton, President
No. 2	Hon. William H. Wiley, Treasurer
No. 3	Mr. Calvin W. Rice, Secretary
No. 4	Col. E. D. Meier, Chairman Finance Committee
No. 5	Mr. S. Edgar Whitaker, Office Manager
No. 6	Mr. M. L. Holman, Nominee for President
No. 7	Mr. George R. Henderson, Chairman
No. 8	Mr. A. E. Forstall
No. 9	Mr. C. W. Baker
No. 10	Mr. W. E. Hall
No. 11	Mr. L. R. Pomeroy
No. 12	Mr. C. R. Pratt

Two editions of the printed Members' Register will be issued and distributed at the morning session on Wednesday and at the reception on Thursday. The names registered up to nine o'clock on Tuesday evening will be included in the first edition. The second edition will close at noon on Thursday.

Private telephone booths with attendants will be found on the ground floor and also on the same floor as the Auditorium. This convenience has been provided so that members may enjoy the meetings and at the same time keep in touch with their offices. Pages will keep members advised of calls.

To enhance the interest of the Meeting several of our Honorary Members have accepted special invitations to be present. Messrs. George Westinghouse, John Fritz, Charles F. Porter, John E. Sweet and others.

Application for membership may be made on the standard form which can be procured at the Registration Desk. The application should be sent to the Secretary who will communicate with the references of the applicants and submit it to the Membership Committee for action.

JANUARY MEETING

The January meeting of the Society will be held as usual on the second Tuesday in the month, January 14, Train Lighting, both gas and electric, will be taken up in a very comprehensive paper by R. M. Dixon, Esq., President of The Safety Car Heating and Lighting Company.

Mr. Dixon's paper will be published in the January Proceedings and members interested in this subject are requested to send in discussion. Advance copies will be sent previous to the publication of the paper to members requesting them. This will afford extra time for preparing discussion.

APPOINTMENT OF A MEMBER OF THIS SOCIETY ON PENNSYLVANIA RAILROAD BOARD

The Board of Directors of the Pennsylvania Railroad elected Percival Roberts, Jr. a member of the Am.Soc.M.E. to a place on its board to succeed Mr. Alex. M. Fox, recently deceased.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The Society of Naval Architects and Marine Engineers will hold their fifteenth general meeting in the Engineering Societies building on Thursday and Friday, November 21 and 22. The members of our Society are invited to attend the sessions and to discuss the papers which may prove of interest to them.

THE LIBRARY

The three libraries of the Founder Societies, located on the top floor of the Engineering Societies Building, are open to the memberships and the public, in accordance with the rules of the Library Committee, until nine o'clock in the evening.

This plan was begun the first week in November. It of course entails considerable expense which the Societies are willing to assume if the libraries are used to an extent which guarantees the expenditure. The use of the Library during the evenings will decide the future policy of the Library Committee.

MEMBER OF AM.SOC.M.E. APPOINTED TO PUBLIC SERVICE COMMISSION

An honor which has come to a member of the Society is the appointment of Mr. Henry B. Seaman as chief engineer of the Public Service

Commission to succeed Mr. George S. Rice, resigned. The term of office of the commissioner is five years with a salary of $15 000 a year.

The Public Service Commission appointed this year combines the duties of several boards provided for the regulation and control of certain public service corporations. Mr. Seaman as chief engineer will administer the functions formerly directed by the Rapid Transit Commission and will have an engineering staff of 350.

Before his appointment to this commission, Mr. Seaman had done important work in elevated and subway constructions of New York, and for the Erie, Pennsylvania, New York, New Haven and Hartford Railroads. He resigns the position of chief engineer of the Bridge Department of New York to take up his new work on the Commission.

THE AM.SOC.M.E TO COÖPERATE WITH THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

The President of the Society has appointed Dr. Alex. C. Humphries and Dr. Frederick W. Taylor as members of a Joint Committee to coöperate with the Society for the Promotion of Engineering Education, together with representatives of other National Engineering Societies, in the examination of all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction and the proper relations of engineering schools to the secondary industrial schools or foremen's schools, and to formulate a report or reports upon the appropriate scope of engineering education and the degree of coöperation and unity that may be advantageously arranged between the various engineering schools.

The Council of the Society for the Promotion of Engineering Education will confer with the membership of the Joint Committee, and a report of the progress of the work of the Joint Committee will be made to that Society within a year and a final report within two years.

PROGRAM

OPENING SESSION

Tuesday evening, December 3, 8:45 o'clock

The President's Address............Prof. F. R. Hutton, New York

THE BROADER USEFULNESS OF THE SOCIETY

A Social Reunion and informal reception will be held in the auditorium after the address, which will give an opportunity for members and guests to meet and exchange greetings. Ladies will be especially welcome.

SECOND SESSION

Wednesday morning, December 4, 9:30 o'clock

Business Meeting. Reports of the Tellers on Election of Members and Report of Standing and Special Committees. New business can be presented at this Session.

GAS POWER

THE RATIONAL UTILIZATION OF LOW GRADE FUELS IN GAS PRODUCERS...............................Mr. F. E. Junge
DUTY TEST ON GAS POWER PLANT.............Mr. J. R. Bibbins
CONTROL OF INTERNAL COMBUSTION FOR GAS ENGINES
Prof. C. E. Lucke
EVOLUTION OF THE INTERNAL COMBUSTION ENGINE
Prof. S. A. Reeve

Buffet luncheon will be served at one o'clock.

INSPECTION TRIP

Wednesday afternoon, December 4, 2:00 o'clock

Members will be the guests of Mr. Charles M. Jacobs, Esq., Chief Engineer of the Hudson Companies, in an inspection of the tunnels under the Hudson River. Complete information will be found in the booklet to be issued at the meeting.

Wednesday evening, December 4, 8:15 o'clock

COLOR PHOTOGRAPHY

Mr. F. E. Ives, Honorary Member and Past President of the New York Camera Club, assisted by Mr. A. R. Stieglitz, author and editor of photographic works will deliver an address on Color Photography,

which will be a complete account of the progress of the art to date, including the development of the Lumière process. The lecture will be illustrated by stereopticon views, with many stereoscopes arranged so that a large number can see the plates at the same time. Ladies are specially invited.

THIRD SESSION

Thursday morning, December 5, 9:30 o'clock

FOUNDRY PRACTICE

THE FOUNDRY DEPARTMENT AND THE DEPARTMENT OF ENGINEERING DESIGN .... Mr. W. A. Bole
MOLDING SAND .... Mr. A. E. Outerbridge
POWER SERVICE IN THE FOUNDRY .... Mr. A. D. Williams
FOUNDRY FOR BENCH WORK, Mr. W. J. Keep and Mr. Emmet Dwyer
VOLUMETRIC STUDY OF CAST IRON .... Mr. H. M. Lane

FOURTH SESSION

Thursday afternoon, December 5, 2 o'clock

FOUNDRY PRACTICE

SPECIFICATIONS FOR IRON, COKE AND METHOD OF TESTING OUTPUT .... Mr. R. Moldenke
FOUNDRY CUPOLA AND IRON MIXTURES .... Mr. W. J. Keep
FOUNDRY BLOWER PRACTICE .... Mr. W. B. Snow
PATTERNS FOR REPETITION WORK .... Mr. E. H. Berry
SOME LIMITATIONS OF MOLDING MACHINES .... Mr. E. H. Mumford

RECEPTION

Thursday evening, December 5, 9 o'clock

The reception will be held in the Engineering Societies Building at 9 o'clock. This is the distinctively social feature of the meeting and the attendance of the ladies is particularly desired. It is urged that no one shall remain away because the exigencies of travel have made evening dress inconvenient. Members must secure cards for themselves and friends to this reception.

FIFTH SESSION

Friday morning, December 6, 9:30 o'clock

THE SPECIFIC HEAT OF SUPERHEATED STEAM .... Prof. C. C. Thomas
ENGINE DESIGN ADAPTED FOR THE USE OF SUPERHEATED STEAM .... Mr. Max E. R. Toltz
POWER TRANSMISSION BY FRICTION DRIVING .... Prof. W. F. M. Goss
CYLINDER PORT VELOCITIES .... Mr. J. H. Wallace
INDUSTRIAL EDUCATION .... Mr. W. B. Russell

RAILROAD TRANSPORTATION NOTICE

Special concessions have been secured for members and guests attending the Annual Meeting in New York, December 3–6. Read carefully the following details.

The Trunk Line Association, the New England Passenger Association, except the Eastern Steamship Company, the Eastern Canadian Passenger Association and the Southeastern Passenger Association have granted the special rate of a fare and one-third for the round trip, when the regular fare is 75 cents and upwards.

a Buy your ticket at full fare for the going journey, between November 29 and December 5 inclusive. At the same time request a certificate, not a receipt. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Find out from your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to Mr. S. Edgar Whitaker at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 6.

d An agent of the Trunk Line Association will validate certificates December 4, 5 and 6. No refund of fare will be made on account of failure to have certificate validated.

e One hundred certificates must be presented for validation before the plan is operative. This makes it important to ask for certificate.

f If certificate is validated, a return ticket to destination can be purchased, up to December 10, on the same route over which the purchaser came.

The Central Passenger Association offer a special concession of two cents per mile in each direction from points in their territory to Buffalo, Pittsburg, Parkersburg and other eastern gateways. From these points a fare and one third for the round trip will apply.

a Send to Mr. S. Edgar Whitaker, Office Manager, 29 West 39th Street, New York, for a *card order* to get a round trip ticket at reduced rates.

b Present the card, identifying you, to your ticket agent December 1, 2 or 3. This will enable you to buy a round trip ticket at the reduced rates, good for return until December 10.

c When ready to leave New York, present your ticket to the New York ticket agent, that he may witness your signature and stamp the ticket, then it will be good for the return journey.

The Western Passenger Association offer revised one-way fares to Chicago, Peoria and St Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs referring to the Central Passenger Association. The card orders must not be presented to ticket agents of western lines, as they will not be honored.

The Trunk Line Association includes the following territory:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville and Washington, D. C.

The Eastern Canadian Passenger Association includes:

Canadian territory east of and including Port Arthur, Sault Ste. Marie, Sarnia and Windsor, Ont.

The Southeastern Passenger Association includes:

Kentucky, all of West Virginia and Virginia south of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville and Washington, D. C., North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi and Tennessee.

The Central Passenger Association includes :

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The Western Passenger Association includes:

North Dakota, South Dakota, Nebraska, Kansas, Colorado; east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri; north of a line through Kansas, Jefferson City and St. Louis, Illinois; north of a line from Chicago through Peoria to Keokuk.

The New England Passenger Association includes:

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

OBITUARIES

CHARLES J. HILLARD

Charles J. Hillard was born December 5, 1846 in New York. He received his education in New Orleans, and coming North in 1862, was apprenticed as machinist at the Morgan Iron Works serving in the machine shop and the drafting room. He was afterward draftsman for A. S. Cameron and Company, New York; chief draftsman, Knapp Fort Pitt Foundry Company, Pittsburg; he was two years manager for John J. Endres, mining engineer and manufacturer, of Pittsburg; from 1873–1876 he was engineer of the Atlas Works Company, Pittsburg; and founded and operated the firm of Hillard, Sterrett and Company, Ltd., 1876–1885.

Mr. Hillard was also secretary of the Sterling Steel Company; manager, Bois and Gazzam, Limited; chairman and resident manager Centre Mining Company, and at one time held a directorship in the Diamond National Bank of Pittsburg.

Mr. Hillard died September 12, 1907.

PETER H. BEEN

Peter Hamilton Been was born in Milwaukee, Wisconsin in 1882. He received his preliminary education in the public schools of Milwaukee, and entered the drafting room of the E. P. Allis Company in June 1898. In 1902 he entered the shop of the Milwaukee Machine Tool Company and at the end of a year returned to the Allis-Chalmers Company where he was made assistant chief draftsman, holding that position until his death in 1907. He was interested in the technical education for apprentices and gave much time to this work.

CONSOLIDATION

The Petition to the Supreme Court of The American Society of Mechanical Engineers and the Mechanical Engineers' Library Association to Consolidate under the Name of The American Society of Mechanical Engineers, and the Order of the Court, Granting the Petition.

At a Special Term, Part II, of the New York Supreme Court, held in and for the City and County of New York, in the County Court House, Borough of Manhattan, City of New York, on the 17th day of October, 1907.

PRESENT:

Honorable James A. Blanchard,

Justice

In the Matter of the Petition

of

The American Society of Mechanical Engineers and of The Mechanical Engineers' Library Association, For an Order Consolidating Them Into One Corporation.

Upon reading and filing the annexed petition of The American Society of Mechanical Engineers,verified on the 15th day of October, 1907; and the petition of The Mechanical Engineers' Library Association, verified the 15th day of October, 1907; and the agreement of consolidation, entered into between The American Society of Mechanical Engineers and The Mechanical Engineers' Library Association, on the 16th day of September, 1907; and the certificate

of approval by the Chairman and Clerk of a meeting of the Fellows of The Mechanical Engineer's Library Association, duly acknowledged on the 15th day of October, 1907; and the certificate of approval by the Chairman and Clerk of a meeting of the members of The American Society of Mechanical Engineers, duly acknowledged on the 15th day of October, 1907;

And it appearing to the satisfaction of the Court from the aforesaid papers that The American Society of Mechanical Engineers and The Mechanical Engineers' Library Association are membership corporations, incorporated under the laws of the State of New York, for kindred purposes, being purposes for which a corporation may be formed under the Membership Corporations' Law of the State of New York; and that the said corporations have heretofore duly entered into an agreement for the consolidation of said corporations, which said agreement sets forth the terms and conditions of consolidation, the name of the proposed corporation, the number of its Directors, the time of the annual election, and the names of the persons to be Directors until the first annual meeting;

That each of the said corporations has duly petitioned the Supreme Court for an order consolidating the two corporations, which said petition sets forth the agreement for consolidation, and a statement of all the property and liabilities, and the amount and sources of its annual income of each of said corporations; and that before the presentation of the said petition to this Court the agreement and the petition were approved by more than three-fourths of the votes legally cast at a meeting of said corporations, separately and specially called for that purpose, which approval, duly verified by the Chairman and Clerk of such meeting, is duly annexed to said petitions;

And the Court being satisfied that the said petition should be granted;

NOW, THEREFORE, Upon motion of Porter and Barnes, attorneys for the petitioners;

IT IS HEREBY ORDERED, That The American Society of Mechanical Engineers and The Mechanical Engineers' Library Association, as they now exist, be and the same hereby are, in accordance with Section VII, Article I of the Membership Corporations' Law of the State of New York, consolidated into one corporation, upon the following terms and conditions; to wit—

That the two corporations be consolidated into one corporation; that all the property now owned by either of the two corporations be owned by the one consolidated corporation; that all the liabilities of either of the two corporations shall be assumed and paid by the

one consolidated corporation; that the members of each of the two corporations shall become, without the payment of any initiation fees, or other dues, members in equal standing in the one consolidated corporation; that the consolidated corporation shall be governed by the Constitution, and By-laws and Rules of The American Society of Mechanical Engineers, as the same exist at the time of the signing of this order; that the name of the new consolidated corporation shall be "THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS," that the number of the Directors of the new corporation shall be twenty-two; that the annual election shall be held on the second Tuesday of December of each year; that the names of the persons to be Directors of the corporation until the first annual meeting shall be:

Frederick R. Hutton,	Richard H. Rice,
Walter M. McFarland,	Walter Laidlaw,
Edward N. Trump,	Frank G. Tallman,
Robert C. McKinney,	Frederick M. Prescott,
Alex Dow,	A. J. Caldwell,
P. W. Gates,	G. M. Basford,
J. W. Lieb, Jr.,	Fred W. Taylor,
Wm. H. Wiley,	John R. Freeman,
A. L. Riker,	Ambrose Swasey,
Geo. M. Brill,	James M. Dodge,
Fred J. Miller,	Edwin Reynolds.

ENTER
J. A. B.
J. S. C.

SUPREME COURT

New York County

In the Matter of the Petition
of
The American Society of Mechanical Engineers and of The Mechanical Engineers' Library Association, For an Order Consolidating Them Into One Corporation.

TO THE SUPREME COURT OF THE STATE OF NEW YORK,—The petition of The American Society of Mechanical Engineers, and The Mechanical Engineers' Library Association, respectfully shows to the Court:

I That The American Society of Mechanical Engineers is a membership corporation, organized and existing under the laws of the State of New York. That it was incorporated on or about the 23rd day of December, 1881, and a copy of the Certificate of Incorporation is hereunto annexed and marked "Exihibit 1."

II That in the year 1890, The American Society of Mechanical Engineers, in furtherance of the objects of its incorporation, being desirous of maintaining a scientific library arranged for the purchase of a piece of real estate, known as No. 12 West 31st Street, Borough of Manhattan, City of New York. That to facilitate the handling of said property, and in view of the large number of members and of officers of The American Society of Mechanical Engineers, the officers and members of the said American Society of Mechanical Engineers caused to be incorporated The Mechanical Engineers' Library Association, which is a membership corporation existing under the laws of the State of New York. The said Mechanical Engineers' Library Association was duly organized on the 25th day of February, 1890. A copy of its Certificate of Incorporation is hereunto annexed and marked "Exihibit 2."

III That the By-laws of The Mechanical Engineers' Library Association provide that all members of The American Society of Mechanical Engineers, upon payment of annual dues of three dollars a year, shall become Fellows of The Mechanical Engineers' Library Association, who alone have the right to vote and to manage and control the corporation, with the exception of the voting privileges, all members of The American Society of Mechanical Engineers are *ipso facto* members of The Mechanical Engineers' Library Association.

IV That immediately upon the incorporation of The Mechanical Engineers' Library Association, it arranged for the purchase of the said real property, No. 12 West 31st Street, for the sum of sixty thousand dollars ($60,000.). Of this sum, a purchase money mortgage was given to the vender of the property for thirty-three thousand dollars ($33,000.), and The American Society of Mechanical Engineers advanced to The Mechanical Engineers' Library Association the balance of twenty-seven thousand dollars ($27,000.) of the purchase price. Subsequently, The American Society of Mechanical Engineers, and the members thereof, cancelled the indebtedness of The Mechanical Engineers' Library Association to The American Society of Mechanical Engineers, so that, on the 1st day of January 1907, The Mechanical Engineers' Library Association owned the said property free and clear from all incumbrances and free from any indebtedness, except the purchase money mortgage of $33,000.

V The library maintained on the premises of The Mechanical Engineers' Library Association was owned by The American Society of Mechanical Engineers and was maintained by the latter Society, The Mechanical Engineers' Library Association being maintained and kept in existence as a subsiduary corporation of The American Society of Mechanical Engineers.

VI That prior to the 1st day of March, 1907, Andrew Carnegie, Esq., established a trust fund for the maintenance of the United Engineering Society Building on West 39th Street, Borough of Manhattan, City of New York; and The American Society of Mechanical Engineers, as one of the beneficiaries of the said trust fund so given and established by Mr. Carnegie, has accordingly removed to the new United Engineering Society Building, at No. 29 West 39th Street, in the Borough of Manhattan, City of New York, and has removed its library there, and is now maintaining the same on the said premises.

VII That the occasion for continuing to own the premises, No. 12 West 31st Street, having, therefore, passed, The Mechanical Engineers' Library Association applied to the Supreme Court for leave to sell its said property, which permission was duly granted, and on the 20th day of March, 1907, The Mechanical Engineers' Library Association duly sold its said property for the sum of one hundred twenty thousand dollars ($120,000), and applied the sum of thirty-three thousand ($33,000.) in payment of the mortgage indebtedness due upon the said property, and has retained the balance of the proceeds, which constitutes the sole assets of the said Mechanical Engineers' Library Association.

VIII That The Mechanical Engineers' Library Association, having

sold its real estate, and there being no reason for its separate existence, it is now desired by both Societies to consolidate the two companies into one corporation, to be known as "The American Society of Mechanical Engineers."

IX A detailed statement of all the property owned by The American Society of Mechanical Engineers is hereunto annexed, and marked "Exihibit 3," and shows total property of the value of ninety-five thousand eight hundred ninety and 86/100 dollars ($95,890,86).

X A detailed statement of all the liabilities of The American Society of Mechanical Engineers is hereunto annexed, marked "Exhibit 4," and shows total liabilities of fifty-four thousand seven hundred sixty-six and 41/100 dollars ($54,766.41.).

XI A detailed statement showing the amount and sources of the annual income of The American Society of Mechanical Engineers is hereunto annexed, marked "Exihibit 5," and shows annual income of the value of fifty-seven thousand dollars ($57,000.).

XII A detailed statement of all the property of The Mechanical Engineers' Library Association is hereunto annexed, and marked "Exihibit 6," and shows property of the value of eighty eight thousand nine hundred ninety-one and 91/100 dollars ($88,991.91).

XIII The Mechanical Engineers' Library Association has no liabilities and owes no money of any kind whatever.

XIV A detailed statement of the amount and sources of the annual income of The Mechanical Engineers' Library Association is hereunto annexed, marked "Exhibit 7," and shows an annual income of two thousand seven hundred eighty-five dollars ($2785.00).

XV That on the 16th day of September, 1907, in accordance with a vote of the Trustees of The Mechanical Engineers' Library Association, and of the Council of The American Society of Mechanical Engineers, the President and Secretary of The Mechanical Engineers' Library Association and of The American Society of Mechanical Engineers, respectively, duly executed an agreement for the consolidation of the Mechanical Engineers' Library Association and The American Society of Mechanical Engineers, in accordance with Section 7 of the Membership Corporation Law of the State of New York, the consolidated corporation to be known by the name of "The American Society of Mechanical Engineers." The said agreement sets forth the terms and conditions of the proposed consolidation, the name of the proposed corporation, the number of its directors, the time of the annual election, the names of the directors to serve until the annual meeting. The original agreement for consolidation is hereunto annexed, and marked "Exhibit 8."

XVI That the petition and the agreement for consolidation were submitted to a meeting of the Fellows of The Mechanical Engineers' Library Association, specially called for that purpose, and as appears from the certificate of approval by the Chairman and Clerk of the said meeting, this petition and the agreement to consolidate were approved by a vote of more than three-fourths of the members present at the said meeting. The original certificate of approval executed by the Chairman and Clerk of said meeting is hereunto annexed and marked "Exhibit 9."

XVII That the petition and the agreement for consolidation were submitted to a meeting of the members of The American Society of Mechanical Engineers, specially called for that purpose, and as appears from the certificate of approval by the Chairman and Clerk of the said meeting, this petition and the agreement to consolidate were approved by a vote of more than three-fourths of the members present at the said meeting. The original certificate of approval executed by the Chairman and Clerk of said meeting is hereunto annexed and marked "Exhibit 10."

XVIII That it is the intention and desire of the members of the two Societies to maintain a library similar to that heretofore maintained at No. 12 West 31st Street, at the new United Engineering Society Building, at No. 29 West 39th Street. That the said library is now and will hereafter be maintained as a free public library, that access to the same is not and will not be limited to members of your petitioners but in a public spirited way is held open freely to the public and to all desiring to consult the books therein contained. That the two Societies have been, to all practical intents and purposes one, and the separate corporate existence of The Mechanical Engineers' Library Association has been maintained merely because the title to the real estate was in the said corporation. That no reason now exists to continue the said separate corporate existence.

WHEREFORE, Your petitioners pray for an order in accordance with the agreement for consolidation, consolidating The American Society of Mechanical Engineers and The Mechanical Engineers' Library Association, upon the following terms and conditions, to wit,—

That the two corporations be consolidated into one corporation; that all the property now owned by either of the two corporations be owned by the one consolidated corporation; that all liabilities of either of the two corporations shall be assumed and paid by the one consolidated corporation; that the members of each of the two corporations shall become, without the payment of any initiation fees or other dues, members in equal standing in the one consolidated

corporation; that the consolidated corporation shall be governed by the Constitution and By-laws and Rules of The American Society of Mechanical Engineers, as the same exist at the time of the signing of this order; that the name of the new consolidated corporation shall be "The American Society of Mechanical Engineers;" that the number of the Directors of the new corporation shall be twenty-two; that the annual election shall be held on the second Tuesday of December in each year; that the names of the persons to be Directors of the corporation until the first annual meeting may be:

Frederick R. Hutton,	Richard H. Rice,
Walter M. McFarland,	Walter Laidlaw,
Edward N. Trump,	Frank G. Tallman,
Robert C. McKinney,	Frederick M. Prescott,
Alex Dow,	A. J. Caldwell,
P. W. Gates,	G. M. Basford,
J. W. Lieb, Jr.,	Fred W. Taylor,
Wm. H. Wiley,	John R. Freeman,
A. L. Riker,	Ambrose Swasey,
Geo. M. Brill,	James M. Dodge,
Fred J. Miller,	Edwin Reynolds.

That no other or previous application for this or a similar order has been made.

And your petitioners will ever pray, etc.

Dated , New York, Oct. 15, 1907.

The American Society of Mechanical Engineers,
By Frederick R. Hutton, *President.*

The Mechanical Engineers' Library Association,
By Henry R. Towne, *President.*

State of New York, }
County of New York, } —ss:

Frederick R. Hutton, being duly sworn, deposes and says, that he is the President of The American Society of Mechanical Engineers, one of the petitioners named in the foregoing petition; that he has read the foregoing petition, and knows the contents thereof, and that the same is true of his own knowledge, except as to the matters therein stated to be alleged on information and belief, and as to those matters he believes it to be true. That the reason why this verification is not made by the petitioner in person is because the petitioner is a

corporation, and deponent is an officer thereof, to wit,—the President, and is familiar with the matters therein set forth.

FREDERICK R. HUTTON

Sworn to before me this
15th day of October, 1907.
CHARLES ALVIN ROGERS
Notary Public No. 62
New York County,
New York.
(Seal)

State of New York,
County of New York, } —ss:

HENRY R. TOWNE, being duly sworn, deposes and says, that he is the President of The Mechanical Engineers' Library Association, one of the petitioners named in the foregoing petition; that he has read the foregoing petition and knows the contents thereof, and that the same is true of his own knowledge, except as to the matters therein stated to be alleged on information and belief, and as to those matters he believes it to be true. That the reason why this verification is not made by the petitioner in person, is because the petitioner is a corporation, and deponent is an officer thereof, to wit,—the President, and is familiar with the matters therein set forth.

HENRY R. TOWNE

Sworn to before me this
15th day of October, 1907.
CHARLES ALVIN ROGERS
Notary Public No. 62
New York County,
New York.
(Seal)

EXHIBIT 1

State of New York
City and County of New York } —ss:

WE, George H. Babcock, William P. Trowbridge, Lycurgus B. Moore, Thomas Whiteside Rae, Alfred R. Wolff, D. S. Hines, Charles E. Emery, James C. Bayles and Frederick R. Hutton, all of whom are of full age, and citizens of the United States; and also citizens of and resident within this State except George H. Babcock, who resides in the State of New Jersey, DO HEREBY CERTIFY

That we desire to associate ourselves together, and form a Society

or association for scientific purposes, pursuant to and in conformity with an Act of the Legislature of the State of New York passed on the twelfth day of April, eighteen hundred and forty-eight, entitled "An Act for the Incorporation of Benevolent, Charitable, Scientific, and Missionary Societies," and the several acts of the Legislature amendatory thereof and supplemental thereto and in accordance therewith do hereby declare

FIRST: The name or title by which such Society shall be known in law shall be THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

SECOND: The particular business and objects of such Society are to promote the arts and sciences, connected with engineering and mechanical construction for scientific purposes, and to that end to meet and associate together, to read and discuss professional papers, and to circulate by means of publications among its members, the information thus obtained, and for the purpose of maintaining a library.

THIRD: The number of Trustees, directors or managers to manage the same shall be eighteen, and the names of the trustees, directors or managers of such Society for the first year of its existence are Robert H. Thurston, William H. Shock, Alexander S. Holley, Theodore N. Ely, William P. Trowbridge, Erasmus D. Leavitt, Jr., Charles E. Emery, Washington Jones, William B. Cogswell, Charles B. Richards, S. B. Whiting, J. F. Holloway, George Fisher, Allan Stirling, George H. Babcock, S. W. Robinson, Charles W. Copeland and Thomas Whiteside Rae.

FOURTH: The business of the said Society or association shall be carried on in the City and County of New York, and the principal office of such Society or association shall be located in said City and County of New York.

WITNESS our hands and seals this twenty-third day of December, A. D., 1881.

In the presence of

WM. L. SNYDER.

GEO. H. BABCOCK, (Seal)
W. P. TROWBRIDGE, (Seal)
LYCURGUS B. MOORE, (Seal)
THOMAS WHITESIDE RAE, (Seal)
ALFRED R. WOLFF, (Seal)
D. S. HINES, (Seal)
J. C. BAYLES, (Seal)
CHAS. E. EMERY, (Seal)
F. R. HUTTON. (Seal)

State of New York }
City and County of New York } ss:

On this 23rd day of December, in the year of our Lord, one thousand eight hundred and eighty-one before me personally came George H. Babcock, William P. Trowbridge, Lycurgus B. Moore, Thomas Whiteside Rae, Alfred R. Wolff, Charles E. Emery, James C. Bayles and F. R. Hutton, to me known to be the individuals described in and who executed the foregoing instrument and severally acknowledged that they executed the same.

WM. L. SNYDER,
Notary Public,
New York County.

State of New York, }
City and County of New York } ss:

On the 24th day of December, in the year of our Lord one thousand eight hundred and eighty-one, before me personally came D. S. Hines, to me known to be the individual described in and who executed the foregoing instrument and acknowledged that he executed the same.

WM. L. SNYDER,
Notary Public,
New York County.

ENDORSEMENT

State of New York }
City and County of New York } ss:

I, ABRAHAM R. LAWRENCE, one of the Justices of the Supreme Court of the first Judicial District of the State of New York, in which the place of business or principal office of the association or Society hereinafter mentioned shall be located, do hereby certify that I have examined the Certificate of Incorporation of the Association or Society designated as "THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS" and the right to establish or organize the same, under the name and for the purposes therein mentioned pursuant to, and in conformity with an Act of the Legislature of the State of New York passed on the twelfth day of April, 1848 entitled "An Act for the Incorporation of Benevolent, Charitable, Scientific and Missionary Societies," and the several acts of the said Legislature amendatory thereof, and the

same meets my approbation and approval and in accordance therewith, I make this endorsement.
Dated New York December 24th 1881.

ABR. R. LAWRENCE,
Justice of the Supreme Court

State of New York
City and County of New York } ss:

I, WILLIAM A. BUTLER, Clerk of the said City and County, and Clerk of the Supreme Court of said State for said County, DO CERTIFY, That I have compared the preceding with the original Certificate of Incorporation of "The American Society of Mechanical Engineers" on file in my office and that the same is a correct duplicate therefrom and of the whole of such original.
Endorsed filed and recorded December 24, 1881.

In witness whereof, I have hereunto subscribed my name and affixed my official seal, this 24 day of December, 1881.

WILLIAM A. BUTLER
(Seal) *Clerk*
(Endorsed)

Certificate of Incorporation
of
The American Society of Mechanical Engineers.

STATE OF NEW YORK
OFFICE OF SECRETARY OF STATE.

Filed and Recorded December 27, 1881.

ANSON S. WOOD
Deputy Secretary of State

EXHIBIT 2

State of New York
City and County of New York } ss:

WE, Stephen Wilcox, Charles H. Loring, Frederick R. Hutton, Horace See, F. Meriam Wheeler, and Stephen W. Baldwin, all of whom are citizens of the United States, and all of whom are citizens of the State of New York, except F. Meriam Wheeler, who resides in the State of New Jersey, do hereby certify:

That we desire to associate ourselves together for the purpose of founding, continuing and perpetuating a library in conformity with an Act of the Legislature of the State of New York, passed on the 15th

day of May, 1875, entitled "An Act for the Incorporation of Library Societies" and the acts of the Legislature amendatory and supplementary thereto and we do hereby further state:

FIRST: That the name of such Society is to be "THE MECHANICAL ENGINEERS' LIBRARY ASSOCIATION."

SECOND: That the business and object of such Society is to be the founding, continuing and perpetuating of a free public library containing a collection of books, pamphlets, charts, models, apparatus and other literary and scientific productions or work relating to the subject of Mechanical Engineering and allied departments of science.

THIRD: That the number of the trustees who shall manage the said Society is to be Nine.

FOURTH: That the name of the Trustees for the first year are

R. H. THURSTON,	HORACE SEE,
E. D. LEAVITT,	COLEMAN SELLERS,
JOHN E. SWEET,	HENRY R. TOWNE, and
J. F. HALLOWAY,	F. R. HUTTON.
GEO. H. BABCOCK,	

FIFTH: That the said Library and the office of the said Society is to be located in the City, County and State of New York.

WITNESS our hands and seals this 25th day of February, A.D. 1890.

F. R. HUTTON,	(Seal)
HORACE SEE,	(Seal)
STEPHEN W. BALDWIN,	(Seal)
CHAS. H. LORING,	(Seal)
F. MERIAM WHEELER,	(Seal)
STEPHEN WILCOX.	(Seal)

State of New York,
City and County of New York } ss:

On this 25th day of February, in the year one thousand eight hundred and ninety before me personally came Stephen Wilcox, Charles H. Loring, Frederic R. Hutton, Horace See, F. Meriam Wheeler and Stephen W. Baldwin, to me known to be the individuals described in and who executed the foregoing instrument and they severally acknowledge that they executed the same.

ARTHUR M. SANDERS,
Notary Public
Kings County.

Certificate filed in New York County.
(County Clerk's Certificate to notary's signature)

ENDORSEMENT

State of New York }
City and County of New York } ss:

I, Edward Patterson one of the Justices of the Supreme Court of the First Judicial District of the State of New York, in which the office of "The Mechanical Engineers' Library Association" is to be located, do hereby certify that I have examined the above given Certificate of Incorporation of the said Mechanical Engineers' Library Association and the right to establish or organize the same under the name and for the purposes therein mentioned pursuant to an Act of the Legislature of the State of New York, passed on the 15th day of May 1875, entitled "An Act for the Incorporation of Library Societies" and the amendatory and Supplementary Acts thereof, and the same meets my approbation and I therefore consent that it be filed and make this endorsement.

Dated New York February 26, 1890.

EDWARD PATTERSON,
Justice of the Supreme Court

EXHIBIT 3

DETAILED STATEMENT OF ALL PROPERTY OWNED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PLANT		
Real Estate, including Engineering Building investment	$11,004.47	
Furniture and Fixtures	1,663.83	
Library Books	12,987.07	$25,655.37
STORES		
Stores, electros and finished publications	$8,747.33	
Pocket List	400.72	
Future "Proceedings"	2.43	
Transactions, vol. 28	365.46	9,515.94
CASH AND QUICK ASSETS		
Cashier's Bank, Farmers Loan and Trust Company	$2,954.52	
Treasurer's Bank	31,102.94	
Savings Bank	8,106.16	
Dues Receivable Arrears $10	90.00	
Dues Receivable Arrears 15	460.00	
Dues Receivable Current 10	620.00	
Dues Receivable Current 15	4,230.23	
Initiation Fees Receivable	575.00	
Accounts Receivable	186.52	48,325.37

Unapportioned Expenses		
Insurance paid, not accrued	$27.64	
Stores, gratuities	451.72	
Adjustments Dr.	4,595.14	5,074.50
Miscellaneous		
Land Fund Committee	$258.10	
Appropriations available 1905–1906	349.92	
Dues to be written off	45.00	
Engineering Building occupancy	6,666.66	7,319.68
Total		$95,890.86

EXHIBIT 4

Detailed Statement of All Liabilities of The American Society Mechanical Engineers

External Liabilities		
Accounts payable	$2,440.99	$2,440.99
Funds		
Land Fund	20,702.93	
Library Development Fund	1,509.94	
Weeks Legacy Fund	62.59	
Initiation Fee Fund	6,182.71	
Life Membership Fund	342.57	28,800.74
Internal Liabilities		
Appropriations Current Year	15,864.46	15,864.46
Miscellaneous		
Dues paid before due	15.00	
Initiation fees paid before due	47.50	
Adjustments, A.	45.44	
Advance Merchandise Payments not Cash Sales	560.37	668.31
Mechanical Engineers' Library Association		6,991.91
Total		$54,766.41

EXHIBIT 5

Detailed Statement of the Amount and Sources of the Annual Income of The American Society of Mechanical Engineers

Memberships, 2800, at $15	$42,000.00
Memberships, 500, at $10	5,000.00
Initiation fees	6,000.00
Sales Publications	4,000.00
Total	$57,000.00

EXHIBIT 6

DETAILED STATEMENT OF ALL PROPERTY OWNED BY MECHANICAL ENGINEERS' LIBRARY ASSOCIATION

Cash	$82,000.00
The American Society of Mechanical Engineers	6,991.91
Total	$88,991.91

EXHIBIT 7

DETAILED STATEMENT OF THE AMOUNT AND SOURCES OF THE ANNUAL INCOME OF THE MECHANICAL ENGINEERS' LIBRARY ASSOCIATION

Subscriptions from Fellows	$325.00
Interest on cash in bank at present rate of	2,460.00
Total	$2785.00

EXHIBIT 8

MEMORANDUM OF AGREEMENT

entered into this 16th day of September in the year one thousand nine hundred and seven, BETWEEN THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, party of the first part, and THE MECHANICAL ENGINEERS' LIBRARY ASSOCIATION, party of the second part;

WHEREAS: The party of the first part is a membership corporation organized and existing under the laws of the state of New York, and was incorporated as such membership corporation on or about the 23rd day of December, 1881, for the purpose of promoting the Arts and Sciences, connected with Engineering and Mechanical Construction for Scientific purposes, and to that end to meet and associate together to read and discuss professional papers, and to circulate by means of publications among its members, the information thus obtained, and for the purpose of maintaining a library; and

WHEREAS: the said party of the first part, in the year 1890, was desirous of acquiring certain real property in the City of New York, for the corporate purposes of the said party of the first part, and especially to maintain its library thereon; and

WHEREAS: the party of the second part is a membership corporation organized and existing under the laws of the State of New York, having been incorporated on or about the 25th day of February, 1890, for the purpose of founding, continuing and perpetuating a free public library containing a collection of books, pamphlets, charts, models, apparatus and other literary and scientific productions

or works relating to the subject of Mechanical Engineering and allied departments of science; the said party of the second part having been incorporated by the members and officers of the party of the first part, for the further purpose of holding title to the real estate to be acquired by the party of the first part; and

WHEREAS: Thereafter, and on or about the 30th day of April, 1890, the party of the second part acquired certain real estate in the City of New York, and in conjunction with the party of the first part, has from then until the year 1907 used the said real property in the City of New York for the maintenance of the library of the party of the first part; and

WHEREAS: under the gift of Andrew Carnegie, Esq., the party of the first part became entitled to the use of the new United Engineering Society Building, donated by the said Andrew Carnegie, Esq., at 29 West 39th Street, in the City of New York, and has accordingly, removed its said library to the said premises; and

WHEREAS: subsequently, and on or about the 20th day of March, 1907, the party of the second part accordingly, by permission of the Supreme Court duly granted, sold its said real estate in the said City of New York, and after paying the mortgages on said property, has retained the proceeds thereof, and has the same now on hand in bank; and

WHEREAS: the purposes of the party of the second part have thus been fulfilled and performed, and the parties of the first and second part hereto desire to consolidate the two corporations into one corporation;

Now Therefore, This Agreement Witnesseth:

FIRST—That in pursuance of and in conformity with Section VII of the Membership Corporations Law, as amended, the parties of the first and second part hereto hereby agree to consolidate the two corporations, upon the following terms, to wit,—

SECOND—That all the property now owned by either of the two corporations shall be owned by the one consolidated corporation; and that all the liabilities of either of the two corporations, shall be assumed and paid by the one consolidated corporation.

THIRD—That the members of each of the two parties hereto shall become, without the payment of any initiation fees, or other dues, members of equal standing in the one consolidated corporation.

FOURTH—That the said consolidated corporation shall be governed by the Constitution, By-laws and Rules of the party of the first part,

as the same are now in existence, until or unless the same shall be amended or revised by the new corporation, as therein provided.

FIFTH—The name of the said consolidated corporation shall be "THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS."

SIXTH—The number of the directors of the new corporation shall be twenty-two (22).

SEVENTH—The annual election shall be held on the second Tuesday of December, in each year.

EIGHTH—The names of the persons to constitute the Council which is the Board of Directors of the corporation, until the first annual meeting, are

FREDERICK R. HUTTON,	RICHARD H. RICE,
WALTER M. MCFARLAND,	WALTER LAIDLAW,
EDWARD N. TRUMP,	FRANK G. TALLMAN,
ROBERT C. MCKINNEY,	FREDERICK M. PRESCOTT,
ALEX DOW,	A. J. CALDWELL,
P. W. GATES,	G. M. BASFORD,
J. W. LEIB, JR.,	FRED W. TAYLOR,
WM. H. WILEY,	JOHN R. FREEMAN,
A. L. RIKER,	AMBROSE SWASEY,
GEO. M. BRILL,	JAMES M. DODGE,
FRED J. MILLER,	EDWIN REYNOLDS.

IN WITNESS WHEREOF, Each of the parties hereto has caused this agreement to be executed by its President and attested by its Secretary, in conformity with the vote of the Trustees of The Mechanical Engineers' Library Association, and of the Council of The American Society of Mechanical Engineers, duly held in accordance with the By-laws of the said corporations.

THE MECHANICAL ENGINEERS' LIBRARY ASSOCIATION,
BY HENRY R. TOWNE, *President*

ATTEST:
H. H. SUPLEE,
Secretary

(Seal)

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS,
BY F. R. HUTTON, *President*

ATTEST.
CALVIN W. RICE,
Secretary

(Seal)

State of New York, }
County of New York, } ss:

On the 26th day of September in the year one thousand nine hundred and seven, before me personally came Calvin W. Rice, to me known, who being by me duly sworn did depose and say; that he resided in Montclair, New Jersey; that he is the Secretary of The American Society of Mechanical Engineers, one of the corporations described in and which executed the foregoing agreement; that he knew the seal of said corporation; that the seal affixed to said instrument was such corporate seal; that it was so affixed by order of the Council of said corporation, and that he signed his name thereto by like order. And the said Calvin W. Rice further said that he is acquainted with Frederick R. Hutton and knows him to be the President of the said Corporation; that the signature of the said Frederick R. Hutton subscribed to the said agreement is in the genuine handwriting of the said Frederick R. Hutton, and was thereto subscribed by the like order of the said Council, and in the presence of him, the said Calvin W. Rice.

Calvin W. Rice

James R. Stafford,
Notary Public,
New York County
(Seal)

State of New York, }
County of New York, } ss:

On the 16th day of September, in the year one thousand nine hundred and seven, before me personally came H. H. Suplee, to me known, who being by me duly sworn, did depose and say; that he resided in New York City; that he is the Secretary of The Mechanical Engineers' Library Association, one of the corporations described in and which executed the foregoing agreement; that he knew the seal of said corporation; that the seal affixed to said instrument was such corporate seal; that it was so affixed by order of the Trustees of said corporation, and that he signed his name thereto by like order. And the said H. H. Suplee further said that he is acquainted with Henry R. Towne, and knows him to be the President of the said Corporation; that the signature of the said Henry R. Towne subscribed to the said instrument is in the genuine handwriting of the said Henry R. Towne, and was thereto subscribed by the like order

of the said Trustees, and in the presence of him, the said H. H. SUPLEE.

H. H. SUPLEE

JAMES R. STAFFORD
Notary Public,
New York County
(Seal)

EXIHIBIT 9

CERTIFICATE OF APPROVAL OF CHAIRMAN AND CLERK OF MEETING OF FELLOWS OF MECHANICAL ENGINEERS' LIBRARY ASSOCIATION.

I, HENRY R. TOWNE, and I, H. H. SUPLEE, being respectively the Chairman and Clerk of the meeting of Fellows of The Mechanical Engineers' Library Association, DO HEREBY CERTIFY that a Special Meeting of the Fellows of the Mechanical Engineers' Library Association was duly called in accordance with the By-laws and Constitution of the said corporation, upon due notice given, and was duly held at No. 29 West 39th Street, in the Borough of Manhattan, City of New York, on the 15th day of October, 1907; and that at said meeting the foregoing annexed agreement to consolidate The Mechanical Engineers' Library Association and The American Society of Mechanical Engineers, and the foregoing annexed petition to the Supreme Court for the consolidation of The Mechanical Engineers' Library Association and The American Society of Mechanical Engineers, were duly submitted to the Fellows thereat, and that more than three-fourths of all the Fellows present, either in person or by proxy, voted in favor of said consolidation.

IN WITNESS WHEREOF, We have hereunto set our hands this 15 day of October, 1907.

HENRY R. TOWNE, *Chairman*

H. H. SUPLEE
Clerk

State of New York,
County of New York, } ss:

On this 15th day of October, in the year nineteen hundred and seven, before me, the undersigned, personally came HENRY R. TOWNE, Chairman, and H. H. SUPLEE, Clerk, to me known and known to me to be the Chairman and Clerk, respectively, of the meeting of Fellows of The Mechanical Engineers' Library Association, and who executed

the foregoing certificate of approval, and they duly severally acknowledged to me that they executed the same.

CHARLES ALVIN ROGERS
Notary Public No. 62
New York County,
New York

(Seal)

EXHIBIT 10

CERTIFICATE OF APPROVAL OF CHAIRMAN AND CLERK OF MEETING OF MEMBERS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

I, F. R. HUTTON, and I, CALVIN W. RICE, being respectively the Chairman and Clerk of the meeting of Members of the American Society of Mechanical Engineers, DO HEREBY CERTIFY that a Special Meeting of the Members of The American Society of Mechanical Engineers was duly called in accordance with the By-laws and Constitution of the said corporation, upon due notice given, and was duly held at No. 29 West 39th Street, in the Borough of Manhattan, City of New York, on the 8th day of October, 1907; and that at said meeting the foregoing annexed agreement to consolidate The Mechanical Engineers' Library Association and The American Society of Mechanical Engineers, and the foregoing annexed petition to the Supreme Court for the consolidation of the Mechanical Engineers' Library Association and The American Society of Mechanical Engineers, were duly submitted to the Members thereat, and that more than three-fourths of all the Members present, either in person or by proxy, voted in favor of said consolidation.

IN WITNESS WHEREOF, We have hereunto set our hands this 15th day of October, 1907.

F. R. HUTTON
Chairman

CALVIN W. RICE,
Clerk

State of New York
County of New York, } ss:

On this 15th day of October, in the year nineteen hundred and seven, before me, the undersigned, personally came F. R. HUTTON, Chairman, and CALVIN W. RICE, Clerk, to me known and known to me to be the Chairman and Clerk, respectively, of the meeting of

Members of The American Society of Mechanical Engineers, and who executed the foregoing Certificate of Approval, and they duly severally acknowledged to me that they executed the same.

Charles Alvin Rogers
Notary Public No 62
New York County
New York.

(Seal)

CONTROL OF INTERNAL COMBUSTION IN GAS ENGINES

By PROFESSOR CHARLES EDWARD LUCKE, NEW YORK
Member of the Society

One of the primary prerequisites for close engine control or regulation, be that engine a steam engine, a gas engine or any other kind of motor, is absolute constancy of cyclic effort with a fixed position of the controlling mechanism. The promptness with which a change of effort will follow a change of setting of the governing or regulating gear depends among other things upon the cycle of operations to be carried out in the cylinder, and, in the case of gas engines, the cycle is such that much time may elapse between a governor movement and the controlling effect desired. This has been clearly pointed out in many papers and as ordinarily called "cyclic influence" it is well understood.

2 It is the object of this paper to examine into the conditions under which constancy of effort may or may not be obtained with constancy of setting of the governor and valve gear. It is possible in gas engines to get many different indicator cards at apparently constant external load, the differences indicating differences of effort and in most gas engines, even with the mechanism for controlling the engine fixed in position, the same variation of indicated effect may be observed. The differences which will appear on the indicator card for apparently identical conditions are not differences in compression, suction or exhaust lines, but almost entirely differences of combustion and expansion lines, or as the expansion line position is fixed by the combustion line, it may be said that the differences are due entirely to variations in combustion lines.

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

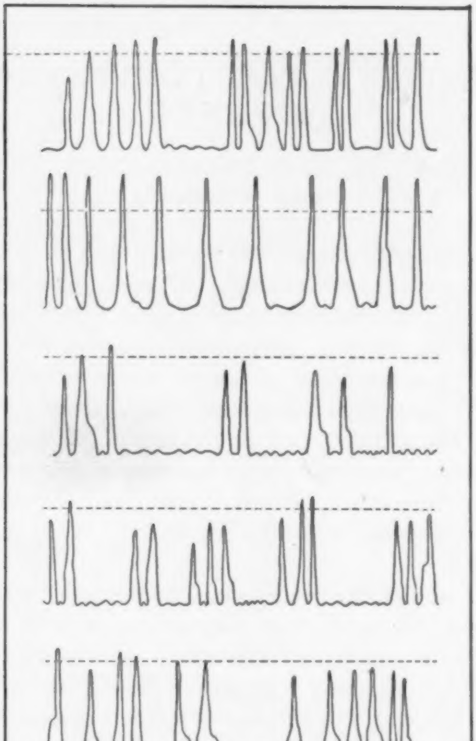

FIG. 1

3 It would appear, therefore, that because combustion lines in gas engines are not identical for apparently identical conditions of the mechanism that we have failed to control this combustion in a manner required by everyday practice in the use and application of gas engines. Whether, however, this failure is due to ignorance on the part of designers, or whether the end sought is in opposition to natural phenomena, will not appear without analysis.

4 As an illustration of some of these variations Fig. 1 is presented and represents a continuous record of the maximum pressure over several strokes in a small gasoline engine governing by holding the exhaust valve open when the load is light, each line giving the results

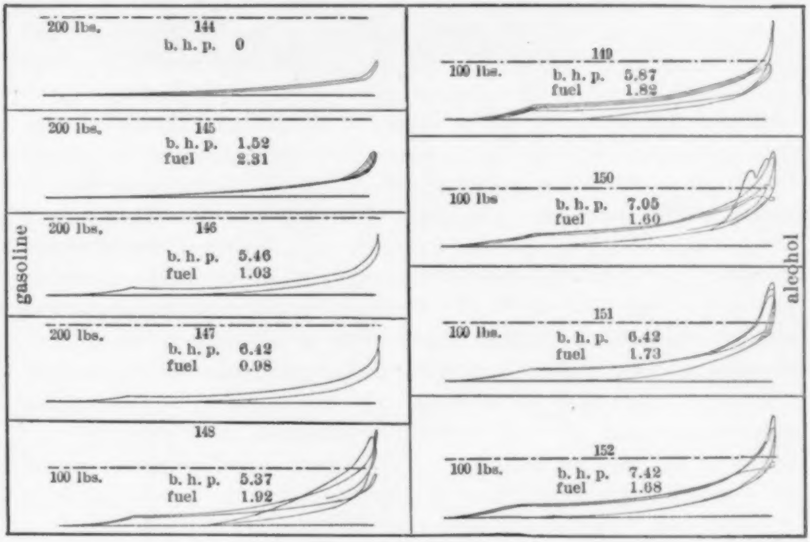

FIG. 2

of one constant adjustment. Aside from the variations produced by the idle strokes, which are, of course, not here considered, it is to be noted that the maximum pressures for any one adjustment which should be identical are not identical, and that in some cases they are more clearly identical than in others.

5 From the set of indicator cards of Fig. 2 it appears that the ignition is sometimes spontaneous or starts from some point on the compression line before the ignitor has acted, indicating preignition of the charge. A still different sort of variation or lack of constancy is shown in Fig. 3; the variations are those due to height of combustion

lines and the form of that part of the combustion line which runs into the expansion line. In Fig. 4 there is presented another indicator card in which not only is there a variation of the combustion line similar to that of Fig. 3, but one of another sort; a violent wave appears at times, different for successive strokes and sometimes absent.

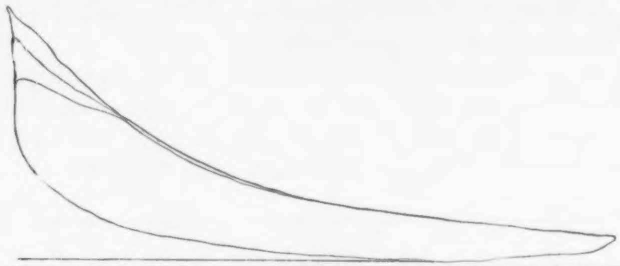

FIG. 3

6 An examination of the indicator cards here presented and many others of a similar kind that every gas engine experimenter has found at some time or other will indicate that the variations in the combustion line are principally of three sorts, running one into the other; first, there may be too early a beginning of the combustion line or preignition, which comes and goes sometimes in the most puzzling fashion, but which at other times can be traced to a removable cause and eliminated; secondly, with an absolute constant ignition and smooth lines successive strokes may indicate a displacement

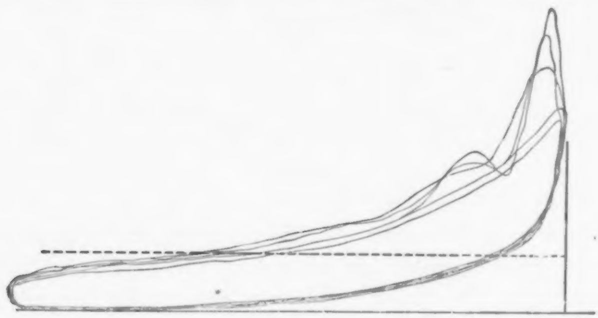

FIG. 4

of whole or part of the combustion line. This is a mixture variation effect. Thirdly, there may be at some time violent waves or even mild waves differing on successive strokes, passing away and recurring at times, and at other times persistently present. This is the phenomenon of the explosive wave.

MIXTURE EFFECTS

7 A variation of mixture may affect the combustion line through a change in the rate of propagation, which results from changes in mixture proportion considered in conjunction with piston speed. A slow burning mixture will tend to give a flatter combustion line with a fixed piston speed than a fast mixture. Likewise, a mixture may begin to burn rapidly and finish slowly, giving succeeding combustion lines which coincide in part, but which vary toward the end where the combustion line runs into the expansion line from the dilution of the last part of the charge by early produced neutral gases. Through excessive dilution of some part of the mixture in the cylinder, which it must be understood is probably not homogeneous, some of the gas may not burn and on succeeding strokes the diffusion may be more or less complete than before, allowing the incompleteness of the combustion to vary toward the end of the process. The actual mixture under combustion consists not merely of air and gas, but rather air, gas and burnt or neutral gases. Any variation of proportion of the quantity of air, gas or burnt gases to the whole that may occur will produce variations in combustion lines, but variations in combustion lines may just as well occur when the proportions of totals are constant, through lack of homogeneity of the mixture on successive strokes.

8 Excluding for the moment a consideration of neutral products the problem of securing a proper proportion of air to gas in the cylinder is one of orifice flow, and the failure to secure it may be analyzed on the basis of the laws covering orifice flow. In this connection it must be remembered that it is not volume proportions that are most important, but rather weight proportions, since it is a definite weight of air that is required to burn a definite weight of gas, although volume proportionality will follow if the pressure and temperature of both the air and the gas are constant and the same, which unfortunately is seldom true. The orifices through which the air and gas flow separately to form the mixture are of very peculiar forms, as a rule, and not the same either in size or form so that the laws of variation of proportion are reducible to the laws of variation in the weight of air per pound of gas flowing through separate orifices of different form and size at probably different temperatures and with different pressure drops or pressure heads.

9 It is well known that the coefficient of efflux for the flow of gases through orifices varies with the size of opening, shape of opening and velocity of flow or pressure head. Air enters the engine

cylinder under the influence of a pressure head represented by the cylinder vacuum. The gas, however, has a pressure higher than atmosphere if pressure gas and lower than atmosphere if suction producer gas, so that while the head causing the flow of air is the cylinder vacuum alone, the head causing the flow of gas when under pressures is the sum of the cylinder vacuum head and its own pressure head, and when under suction is the difference between the cylinder vacuum and the gas pipe vacuum. Gas pressures are, moreover, never constant in practice nor will any of the gas pressure regulators proposed and used make them constant nor reduce them uniformly to atmosphere because they always involve inertia effects of moving solid parts and of the gas itself.

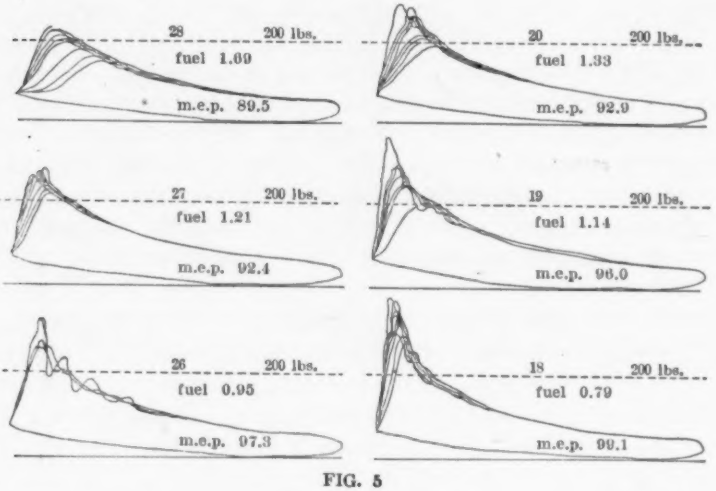

FIG. 5

10 With a fixed opening the cylinder vacuum head acting on the orifices is a variable because piston speed in engines varies from zero to a maximum and back to zero for every suction stroke. This variable vacuum head with fixed gas pressure head either positive or negative causes a variation in the ratio of the total head on the gas orifice to the total head on the air orifice and hence has the effect on varying proportions of air to gas throughout the stroke. In addition to this, whenever the gas is under pressure, and the opening fixed, the idle engine period, that is, the period of no suction, allows time for the pressure gas to flow past the orifice and collect in the air chamber, which would tend to make the mixture rich in gas at the beginning of the next stroke.

11 Intermittence of flow is another element which enters into the variation of proportion because it brings into play the inertia of the gas and the inertia of the air. A stream of air or gas cannot be started or stopped instantly, and as the masses to be moved are not the same the inertia will not be the same for the two, and one will tend thereby to lead in its flow over the other one, that which has the smaller mass leading. At the end of suction that which has the greater mass will continue its motion for the longer time.

12 It appears, therefore, to be an extremely difficult proposition, viewed entirely independent of the gas engine, to secure constant weight proportion between two gases flowing through two orifices into a partial vacuum through openings of different sizes and shape under heads compounded of the vacuum and the gas pressure with variable rates of flow, changes of barometer, gas pressure and the temperature of both gases and it is not surprising that variations

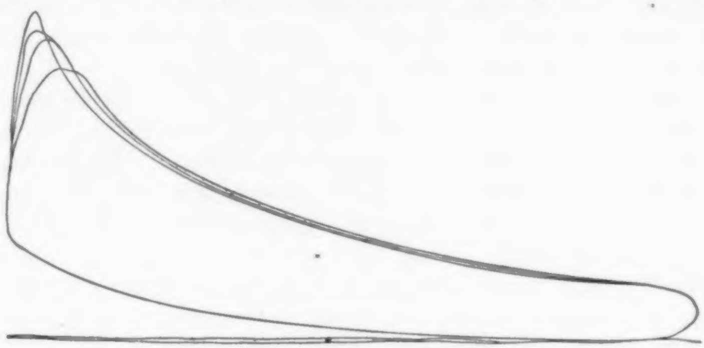

FIG. 6

occur, but rather more surprising that the results are as uniform as they are. After having proportioned the air and the gas, the mechanism delivers it into a cylinder through a valve to an irregular head or clearance space where it mixes more or less uniformly with the neutral gases therein. These residual gases may have the same composition on successive strokes or may not, depending upon a variety of circumstances, some uncontrollable, such as diffusion, others under practical control, such as point of ignition and back pressure. A rather aggravated case of this mixture variation effect on various engine settings is given in Fig. 5, the fuel being gasolene and the engine a small one.

13 Another case not so aggravated, but much more common is shown in Fig. 6. This is from a medium size engine running on city gas. It is to be distinctly understood that the mixture variations

which occur in a hit-and-miss governed engine, before and after misses when the combustion chamber contains in the one case air after a miss and in another case burnt gases after an explosion, are excluded from this discussion and only the variations which occur in engines operating under steady and uniform conditions included.

EXPLOSIVE WAVES

14 The French scientist, Berthelot, gave the name "explosive wave" to a certain phenomenon observed in the combustion of explosive mixtures, which phenomenon was later more fully investigated by Mallard and Le Chatelier in "*Recherches Expérimentales et Théoriques sur la Combustion des Mélanges Gazeux Explosifs,*" and in recent years by Dixon and Bradshaw, Crussard and many others, which phenomenon may easily occur and does occur in gas engine cylinders. In some cases it is possible to define the conditions which will produce it and in other cases it is not. Examining the rate of propagation through a tube it is found that at times the propagation is uniform, at times mildly undulatory, indicated by waves of small amplitude, and at times violently undulatory, indicated by waves of great amplitude accompanied by shock and sound. This violently undulatory propagation has an extremely high rate and can be produced whenever there is a violent agitation of the mixture about to be ignited.

15 One sort of agitation producing this result and in use by early experimenters was a small stream of the mixture impinging into the main mass. An apparently different agitation though probably identical studied especially by later experimenters is a pressure wave or compression wave. It can be shown that if combustion be started in a tube, closed at one end, waves may set up so violent as to cause extinction before the passage through the tube is completed. In this case the agitation is a result of a compression wave produced by the combustion itself. In engine cylinders this same sort of wave may exist. The motion of the piston itself during compression produces a compression wave which advances before it through the mixture and which probably reflects and superimposes or neutralizes, as accident may dictate, so that the entire mass is in a process of agitation during compression.

16 Inflammation started in such a mixture agitated either by streams of gas as the result of pockets in the combustion chamber or by compression waves, will sometimes be very violent, giving a true explosive wave, but may not exist at all. This seems to indicate

that the violent momentary pressures of the explosive wave crest result only, when advancing waves superimpose one on another and synchronize with their reflections.

17 A simple experiment that can be performed by anyone will yield explosive waves of this sort on any gas engine if between the indicator and the engine cylinder there be connected a pocket with a small throat, which may be made of pipe fittings. An engine which

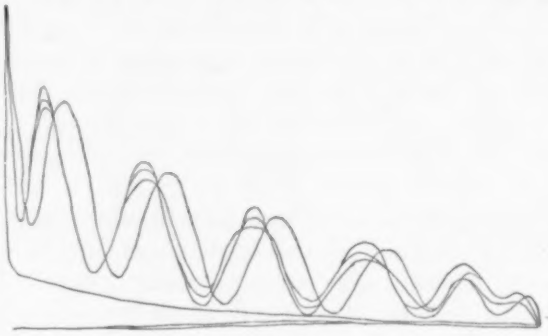

FIG. 7

gives a perfectly smooth combustion line without such a pocket will give with the pocket explosive waves even when the ignition is quite late. In nearly every engine these waves will be produced when the ignition takes place before dead center, that is, during the time when the mass is agitated by compression waves from the piston.

18 Fig. 7 shows an explosive wave from a kerosene engine having no hot bulb and a very good form of combustion chamber. Fig.

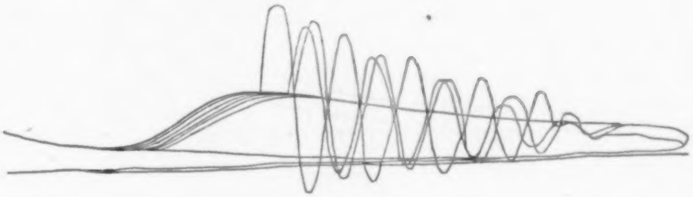

FIG. 8

8 shows for even very late ignition an extremely violent wave, so violent that it is shown for only part of the stroke, the pencil having jumped from the paper for the rest of the stroke. Fig. 9 shows a curious modification of this wave with a sort of harmonic at the crest. Fig. 10 is a record of a violent wave in a large oil engine of the hot bulb class, and Fig. 11 shows another less violent wave

taken from the same engine shortly after. These pressure waves are not to be confused with the occasional fluctuations of the indicator pencil due to the natural period of vibration of the piston and parallel motion of the indicator, although, according to my experience, the confusion is more likely to be the other way, the vibration of the indicator parts being more often the only explanation for the waves that are found.

FIG. 9

19 It is interesting to compare these waves with the work of Mallard and Le Chatelier, especially that part of it in which they report photographically some explosive waves of light. By passing a photographic plate across a tube in which the mixture is to be burned, the record will give an indication of the rate of propagation because one coördinate will represent time and the other will represent distance traveled by the flame. Fig. 12 and Fig. 13, reproduced

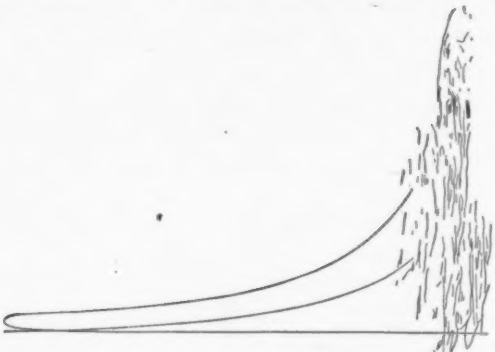

FIG. 10

from their report, show not only the primary uniform propagation indicated by the straight line, but also the violent explosive wave effects indicated by the wave of great amplitude, which ceases abruptly because it causes extinction. These waves are light waves and very similar indeed to the actual pressure waves recorded by our indicators. Occurring in engine cylinders they are elements not only of danger, but of interference with control and require attention

for their elimination, but even in spite of great care often refuse to yield to any sort of treatment and persist in spite of the application of remedies.

PREIGNITION

20 Whenever on compression a mixture ignites itself before dead center the phenomenon is called "preignition." Besides the many known easily avoidable causes, there are some that are difficult to understand. Any inward projecting part, such as a piece of asbestos gasket or rough edge of the casting, a bolt head, nut, piston compression plate, carbonized oil or possibly an ignitor, may get so overheated as to cause ignition. The compression causes a temperature increase, measured by the degree of the compression so that all parts of the gaseous mixture, except those directly in contact with cold walls, will suffer the same temperature rise, due to the compression.

FIG. 11

If there is near any particle of mixture another source of heat than the compression the temperature at that place will rise higher and may rise so much higher as to cause an ignition. It may be also that lack of homogeneity in the mixture will result in zones where the mixture has a lower temperature of ignition than at other places, for example, in places where lubricating oil is vaporizing or in the case of gasolene where the mixture is a little more rich in gasolene. This is another cause. In spite, however, of these traceable causes there seem to be some others, and these are mostly associated with the percentage of hydrogen in the gas.

21 At one time it was believed that the temperature of ignition of hydrogen was so low that the addition of hydrogen to a gas not previously containing it would lower the temperature of ignition of the mass, and designers, including the writer, went so far as to

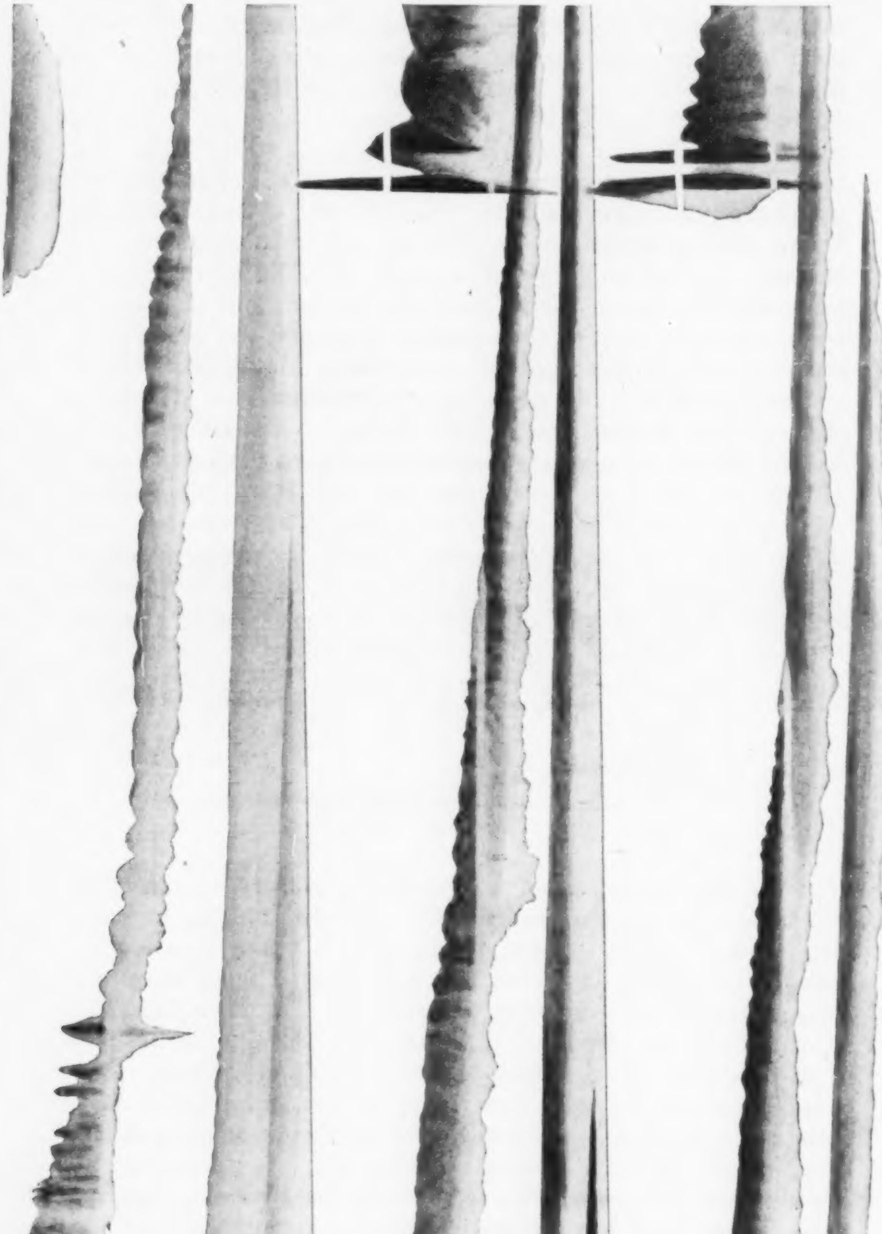

FIG. 12

FIG. 12

FIG. 13

announce figures for the reduction of compression for each per cent of hydrogen present that was necessary to prevent preignitions.

22 Repeated experiments by the different engine builders and by engineers not associated with the building of engines point conclusively to the fact that preignition may occur when the percentage of hydrogen is low and may not occur when it is high and again may occur when it is high and may not when it is low for a given engine running on a given compression, but there seems to be substantial agreement on the statement that if the hydrogen were absent there would be no preignition at this compression.

23 A considerably detailed investigation carried on partly in the laboratory at Columbia and partly in the field seemed to indicate that it was not the percentage of hydrogen in the gas that fixed the tendency to preignite, but rather some ratio of the hydrogen to the other elements present. The remedies applied commonly for preignition troubles are two-fold; first, a reduction in compression; second, an introduction of neutral elements, such as water to be vaporized into steam, steam itself or cooled and purified exhaust gases. This practice introduces greater variations in the mixtures than it is desirable to have, and is justified only in emergency, that the engine may continue to run.

24 An examination of the old values of the temperature of ignition for explosive mixtures throws no light whatever on the solution of this phenomenon, but some more recent determinations do. By dropping a weight on a plunger, closely fitting a cylinder containing a known gas mixture and measuring the plunger travel up to the point where it is stopped by the explosion the temperature of ignition may be calculated by the adiabatic law from the volume ratio in compression when the ignition takes place by the compression alone. This method of measurement was employed by Dr. K. G. Falk in the mechanical engineering laboratories of Columbia and gave for repeated trials of the same mixture at different times the results so consistently uniform that they seem to be very valuable. These were reported in the October meeting of the American Chemical Society and are here summarized.

HYDROGEN AND OXYGEN

Mixture by volumes	Atmospheres adiabatic compression	Ignition temperature corrected for moisture deg. cent.
$4H_2 + O_2$	47 maximum	878
$2H_2 + O_2$		813
$H_2 + O_2$	33 minimum	787
$H_2 + 2O_2$		803
$H_2 + 4O_2$		844

25 This indicates that the temperature of ignition of H and O varies with proportions and is lowest not for the mixture that burns to steam, but for equal parts so that H_2O_2 is the first product formed. The temperatures are those resulting from adiabatic compression to 33 atmospheres minimum and 47 atmospheres maximum, several times higher than ever attained in gas engines of the ordinary type.

CARBON MONOXID AND OXYGEN

Mixture by volume	Atmospheres adiabatic compression	Ignition temperature corrected for moisture deg. cent.
$6\,CO + O_2$	76 maximum	994
$4\,CO + O_2$		901
$2\,CO + O_2$	43 minimum	874
$CO + O_2$		904

26 The lowest temperature is obtained with the mixture $2CO + O_2$ with 43 atmospheric compressions which lies between the maximum and minimum for H and O, but the maximum value of 76 atmospheres for $6\,CO + O_2$ is much higher than the highest for H and O. It is interesting to note also that equal additions of CO or O act the same in raising the temperature of ignition.

27 The addition of neutral nitrogen to the H and O mixtures always raises the ignition temperature and the new temperature T_{HON} for the mixture containing N may be written as a function of the old temperature $T_{H,O}$ as follows:

$$T_{H,O,N} = T_{H,O} + 30n$$

in which

$$n = \frac{\text{volume of inert gas}}{\text{volume of } H_2 \text{ or } O_2 \text{ (whichever is smaller)}}$$

Thus, the addition of $4\,N_2$ to the $H_2 + O_2$ mixture, which has the lowest temperature of ignition, raises the ignition temperature from 787 deg. cent. to 907 deg. cent., a value higher than for any of the H and O mixtures.

28 Similarly, for the CO and O mixtures an equation was found giving the temperatures resulting from additions of N, which is

$$T_{CO,\,O,N} = T_{CO,\,O} + 80\,m$$

$$\text{in which } m = \frac{\text{volume of inert gas}}{\text{volume of CO}}$$

29 Combinations of H, CO and O which approach the producer gases were found to have ignition temperatures which followed the

law of rise by addition of neutral. If the ignition temperature of the H and O part be calculated, considering the CO as inert and that for CO and O part calculated considering the H as inert then the lower value is found to agree with the observations by test. This indicates that the ignition temperature of complex mixtures is fixed by two of its components and their proportions to each other, all else acting to raise the temperature as inert or neutral gases.

30 Trials of alcohol gave a temperature of 973 deg. cent. at 62 atmospheres and fairly constant for over 100 per cent variation in quantity, while gasolene gave 902 deg. cent. with 47 atmospheres, constant for more than 300 per cent range in quantity.

31 These results explain the apparent inconsistency between percentage of hydrogen in the gas and the conditions of preignition. It appears from the figures given for the temperature of ignition that in a producer gas containing hydrogen and CO with various neutrals mixed with oxygen the temperature of ignition does not depend on either the hydrogen necessarily nor the CO necessarily in the mixture, but on the relation that one of these bears to the oxygen present and which one can be determined only by computing the temperatures of ignition for the value and taking that value which is lower. One very significant fact in addition to the above is brought out by these results, and that is that the ignition temperatures and compressions formed are all very much higher than those used in engines. No ordinary engine uses compressions anywhere near those determined for preignition.

32 It is evident, therefore, that as preignitions occur they are due not only to the compression, but also to other sources of heat. The interior parts must be hot enough in places to materially augment the temperatures produced by compression alone. As the final temperature, due to compression, bears a fixed relation to the initial temperature for any given compression that final temperature may be made higher not only by heat additions during the compression, but by a higher initial temperature. High temperature burnt gases retained in the cylinder are, therefore, detrimental and scavenging would be an assistance, but it is doubtful if initial temperatures are high enough in actual engines to account for the preignitions which occur, judged in the light of these ignition temperatures measured, and it is, therefore, extremely likely that all heat effects, not necessarily for the entire cylinder, but for some part, are the real causes and in addition the occasional presence of a certain sensitive proportion between oxygen and either CO or hydrogen.

33 The solution of the problem of controlling preignition resolves

itself into three parts; *a* Maintenance of proportion of the elements of the mixture to those having the higher temperature of ignition, provided this mixture will still contain enough oxygen to burn all the fuel present; *b* Care in securing as low an initial temperature of the mixture as possible by maintaining inlet passages cool and purging the cylinder as completely as possible of burnt gases. This also involves the maintenance of early ignition to reduce final release temperatures. *c* Care in designing the machine so that interior parts shall be as well cooled and as uniformly cooled as possible. A well cooled cylinder with one spot, such as a nut, poorly cooled may just as well be poorly cooled throughout.

34 The prevention of explosive waves entirely in engine cylinders seems to be impossible. They can be avoided to a large extent and practically eliminated by giving attention to the form of the combustion chamber and to the method of igniting so as to avoid the generation of successive waves that might superimpose, but precisely how this is to be done cannot be said at this time, and more research will be required before a solution is possible. It may appear in the light of complete information that no solution will ever be possible.

35 The maintenance of uniform cylinder mixtures involving, as it does, first, the correct and positive proportioning of air to gas, and later, the uniform mixing of this primary mixture with the burnt cylinder gases in always constant quantities, is a thing which is absolutely impossible with the present type of engine. Careful design can do much, but I feel it cannot overcome, so long as present types are adhered to, the numerous difficulties here presented.

36 These three phases of the general subject of our lack of control of internal combustion in exploding engines, namely, the maintenance of mixture proportions, the elimination of explosive waves and preignitions are all worthy of much study and are all difficult problems in themselves. It is hoped that in this presentation of the conditions to be met that designers and builders of these engines, as well as the users, may be led to continue the investigations and to announce their results.

A VOLUMETRIC STUDY OF CAST IRON

By HENRY M. LANE, CLEVELAND, O.

Member of the Society

Engineers in dealing with metals are accustomed to speak of the percentage of impurities present with reference to the weight of the entire mass and the impurities. As a rule no attention is paid to the relative volumes occupied by these impurities, and this neglect probably accounts for many of the seeming contradictions in the behavior of alloys.

2 Cast iron in its various forms may be considered as an alloy. By weight it rarely contains more than 94 per cent metallic iron or pure iron, and in some cases scarcely more than 90 per cent. Many attempts have been made to account for the apparently disproportionate effect produced by the addition of comparatively small amounts of impurities. If, however, we consider the relative volumes occupied by these impurities by themselves, and also the volumes probably occupied when in combination with the cast iron, we obtain an entirely new light upon the subject.

3 The ordinary No. 2 foundry iron contains 2 per cent of silicon, 0.04 per cent of sulphur, 0.70 per cent phosphorus, 0.70 per cent manganese, and 3.50 per cent carbon; or a total of 6.94 per cent of the principal so called impurities. Some of these elements we have been familiar with in their pure state for a long time; such as sulphur, phosphorus, and carbon. Manganese has only recently been obtained in a practically pure state by the thermit process, and silicon in a pure state by the electric furnace.

4 Manganese is a metal very closely related to iron, and having nearly the same specific gravity, and hence when it is alloyed with iron it changes the volume of the mass but little. Some of the other ele-

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ments, however, behave very differently. Pure silicon has a specific gravity of less than 2, while iron has a specific gravity variously reported from 7.77 to 8.0. This means that a given weight of pure silicon occupies four times the volume of a given weight of iron; therefore we may call the volume factor for silicon, 4. In like manner we find that sulphur occupies more than four times the volume of iron, and its volume factor would then be 4.07. The volume factor for phosphorus would be 4.44, and the volume factor for manganese 1.01.

5 Carbon in the graphitic form, which is practically the condition in which it occurs in grey cast iron, occupies more space than any other of the constituent elements, and its volume factor would be 6.79.

6 Using these factors, we may make some very interesting calculations concerning some of the more common iron mixtures, and these will lead us to an understanding of a number of the peculiarities of castings.

TABLE 1

PERCENTAGES OF THE ELEMENTS IN VARIOUS CLASSES OF IRON, BY BOTH WEIGHT AND VOLUME

	NO. 2 FOUNDRY IRON			STOVE PLATE			MACHINERY IRON			MALLEABLE IRON		
	Per cent	Factor	Per cent volume	Per cent	Factor	Per cent volume	Per cent	Factor	Per cent volume	Per cent	Factor	Per cent volume
Si...........	2.00	4.00	8.00	2.47	4.00	9.88	1.30	4.00	5.20	0.70	4.00	2.80
S...........	0.04	4.07	0.16	0.09	4.07	0.37	0.05	4.07	0.20	0.04	4.07	0.16
P...........	0.70	4.44	3.11	0.51	4.44	2.26	0.43	4.44	1.91	0.15	4.44	0.66
Mn..........	0.70	1.01	0.70	0.26	1.01	0.26	0.22	1.01	0.22	0.20	1.01	0.20
C...........	3.50	6.79	23.76	4.19	6.79	28.45	3.90	6.79	26.48	3.00	6.79	20.37
Total........	6.94		35.73	7.52		41.22	5.90		34.01	4.09		24.19

7 Table 1 gives the percentages by weight and by volume of the elements contained in No. 2 foundry iron, in stove plate, machinery iron, and annealed malleable iron. Some explanation is necessary concerning the different mixtures. Each of these analyses was taken from an actual analysis of a standard brand or a casting. In the case of the stove plate, the percentage of phosphorus is lower than that often found. The silicon is lower than that which occurs in many stove plate castings.

8 The machinery iron is also a rather low silicon mixture. Mixtures somewhat low in these elements were chosen for a purpose, on account of the fact that it was not desired to show the most radical

limits, but rather the average. In the case of the malleable casting, the percentage of carbon present of course varies greatly between the surface and the interior of the casting.

9 Believing that the mind sometimes recognizes these differences more keenly through the eye when they are expressed graphically, the diagrams shown in Fig. 1, 2, 3, and 4 have been prepared. Fig. 1 illustrates the relative amounts of impurities in No. 2 foundry iron

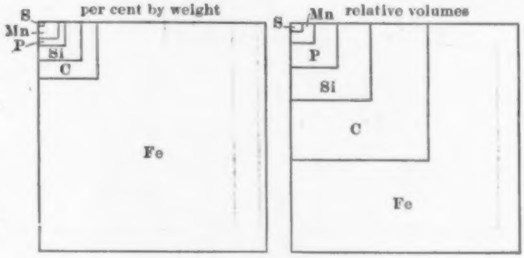


FIG. 1

by weight and by volume. The squares at the left represent the relative amount of the different elements by weight, while those at the right represent the proportion of the elements by volume. Fig. 2 illustrates the amounts of the elements in stove plates. The figure at the left shows the amount of the elements by weight, while the areas in the figure at the right indicate the proportion of the different

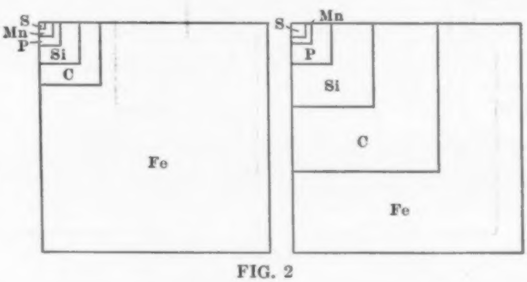


FIG. 2

elements by volume. Note that the area occupied by the manganese in the two diagrams is practically the same, due to the fact that the specific gravity is about the same as that of iron. Fig. 3 shows the relationship between the weights and volumes in machinery iron. The diagram at the left shows the percentages by weight and that at the right the percentages by volume. Fig. 4 illustrates the relationship between the percentages by weight and volume of the con-

stituents of annealed malleable iron. The diagram at the left shows the percentages by weight and the one at the right the percentages by volume. On the left in each case the areas represent the percentages of different impurities by weight, while on the right the areas represent the relative volumes. These diagrams and figures show that the stove plate has over 40 per cent impurities by volume.

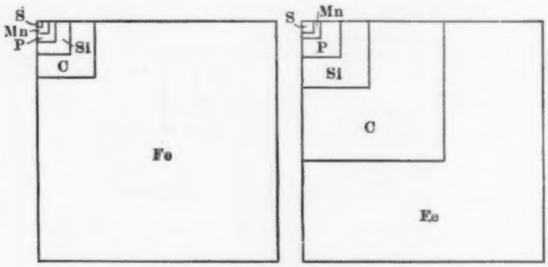


FIG. 3

10 This has been very nicely proved by an actual demonstration in which as much of the iron as possible was removed from the castings by a long pickling in dilute hydrochloric acid. The pickle was a wash used for dipping the castings into previous to nickel-plating. Some castings fell by accident to the bottom of the vat and remained there several months. When they were removed it was found that

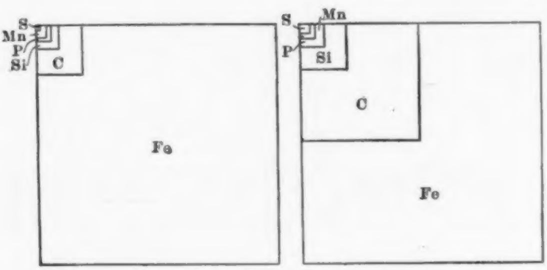


FIG. 4

they were exceedingly light; and while they looked exactly like iron castings, they were brittle and very difficult to handle without breaking. An analysis showed that by far the largest portion of the iron had been removed by the pickle, and hence the remaining constituents formed simply a skeleton or sponge.

11 One of these castings which was subjected to the pickle is shown in Fig. 5, and a section of it in Fig. 6. Fig. 5 is an ornamental casting made of stove plate iron and pickled for several months, thus

removing practically all of the iron. Fig. 6 is a section of the casting shown in Fig. 5. Note on the left the distinct division line in the center of the casting which is formed between the lines of vertical crystals radiating from the surface to the center. A group of castings is also shown in Fig. 7. Attention is called to the fact that the casting on the extreme right is a trunnion or hub which was formerly

FIG. 5

on a considerably larger casting. When this was cast there was a quarter-inch wrought iron rod cast into the hole shown in the upper part of the casting. This rod projected some distance, forming the support for other parts. The wrought iron rod was entirely dissolved by the pickling solution, leaving a clean hole in the skeleton casting which remained. An interesting fact is that careful measurements show that there is practically no change in the size of the castings due to the dissolving of the iron in this manner

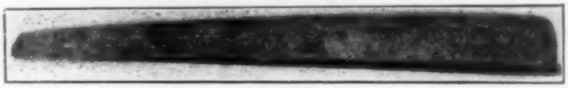


FIG. 6

12 These resulting spongy castings, however, show the character of the original castings remarkably well. It is a matter of common knowledge that a casting sets or solidifies from the outside in; and hence we would expect to find a dividing plane along the center of the casting. When all of the iron is present, this dividing plane is not noticeable. In Fig. 6, which is a section of the casting shown in Fig. 5, and from which the iron has been dissolved, the plane is quite clearly visible, particularly at the left. In Fig. 8, which is an

end view of one of the broken castings shown in Fig. 7, it will be noticed that the structure seems to be banded in layers parallel to the outside surface, as shown in the fracture.

13 This matter of relative volumes dovetails closely into facts which have been known of other castings of various kinds. It is known that when malleable castings are first poured the carbon is practically all in the combined state, and that the castings shrink about one-quarter inch per foot from the pattern size. When the

FIG. 7

castings are annealed, they expand about one-half of the amount which they originally shrunk, or one-eighth inch per foot.

14 During this expansion the carbon is changed from the combined form to a very finely divided graphitic state, which is known as temper carbon. A long annealing in the presence of an oxidizing medium will remove practically all of this carbon from the castings, but results in a weakened casting.

15 This volume study also offers an explanation as to why this long annealing and removal of the carbon weakens the casting. In

FIG. 8

the first place, if the carbon could be taken from the malleable casting without any other change, we see that it would result in about 20 per cent of the bulk of the casting being removed. In other words, the annealed malleable casting would contain 20 per cent of voids. These open spaces would certainly not strengthen the casting, as it stands to reason that the carbon which formerly occupied them would certainly support the iron about it to some extent. This carbon as it exists in the annealed casting is undoubtedly highly compressed, as is attested by the expansion of the iron due to the

change in the carbon and in this compressed state would assuredly form a support to the surrounding metal.

16 But the carbon cannot be removed without involving other changes. If this carbon were to be removed by oxidation, it is certain that some of the iron would also be oxidized, and that the iron oxid thus formed would fill some if not all of the spaces left by the carbon. The iron would therefore be weakened not only by the removal of the carbon, but by the oxidation of a portion of the iron. This undoubtedly explains why a malleable casting which has been heated just above the recalescence point and held there merely long enough to convert all of the carbon from the combined to the

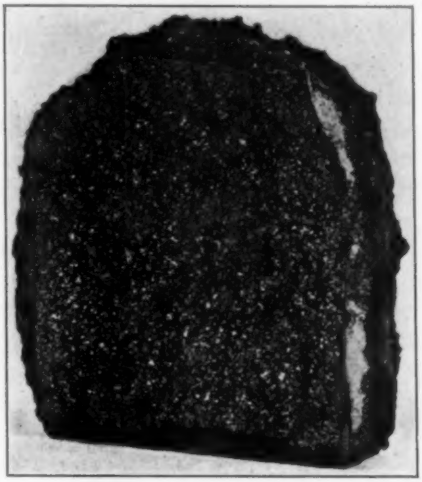


FIG. 9

temper form, without the removal of any of the carbon, is in its strongest condition.

17 In the case of stove plate where the elements constitute over 40 per cent of the volume of the metal, we can readily believe that the extreme fluidity of the iron is to a large extent due to the great percentage of impurities present. It will be noted that the phosphorus factor is high; and hence high phosphorus, which has always been found to produce fluidity, would be expected to exert a great influence, on account of the large volume which it occupies.

18 Of course the phosphorus is undoubtedly combined chemically with the iron, hence there is probably an error in considering it in its elementary or pure condition, but in the absence of exact data on

this point it is impossible to state just how this and other elements do affect the mixture which we commonly call cast iron.

19 Simply to illustrate the difference in the fracture of the various classes of metal, some characteristic broken sections are illustrated in this paper.

20 Fig. 9 shows the fracture of an ordinary pig or No. 2 foundry iron. It will be noted that the fracture is very coarse and crystalline. Fig. 10 shows the fracture of a test piece taken from an air furnace heat. This contains very much less carbon than was found in the No. 2 foundry iron. The silicon has also been reduced and

FIG. 10

the grain is much closer. Four of the principal elements contained in iron are shown in Fig. 11: the upper left hand piece is 99 per cent pure silicon, the upper right hand pure sulphur, the lower right hand pure phosphorus, and the lower left hand pure manganese. The phosphorus is of such a waxy nature that it is difficult to obtain a typical fracture; the other three samples, however, all show characteristic surfaces.

21 In order to bring this volume matter out very clearly, Fig. 12 has been arranged, showing the difference between the relative percentages in Swedish iron and in stove plate. In each case the large square represents 100 per cent.

22 In the left hand figure the small square in the center repre-

sents the impurities in Swedish iron by weight and the square surrounding it the impurities in stove plate by weight. In the right hand figure the two inside squares represent the volume of the impurities in Swedish iron and the volume of the impurities in stove plate. From this we can readily see why the comparatively soft and ductile

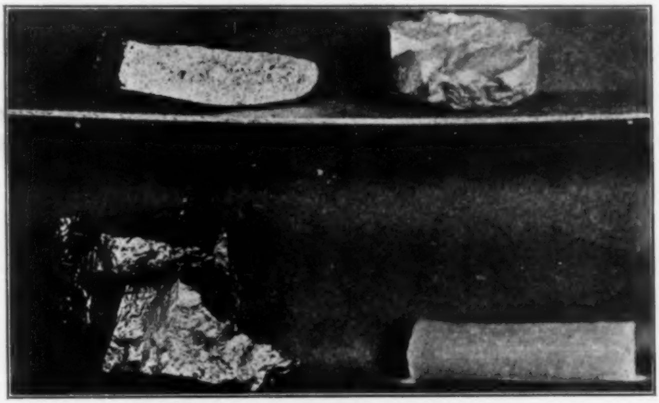


FIG. 11

Swedish iron is changed so completely by the introduction of only about 7 per cent by weight of impurities.

23 The foregoing facts have been confirmed by a number of cases which have come under the observation of the writer or have been related to him by other engineers, and the matter is here presented in the hope that some one else will take up the investigation and carry it much farther.

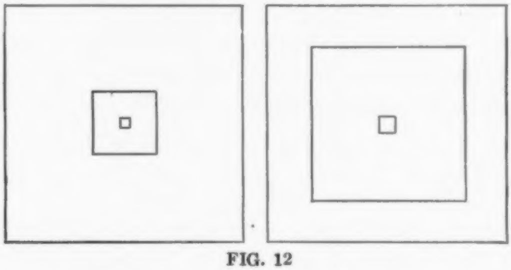


FIG. 12

24 The fact that the impurities in cast iron take up such a very large proportion of the volume is the reason why we have thus far been unable to apply the microscope to cast iron with the same gratifying results which have followed its application to the metallurgy of steel.

DUTY TEST ON GAS POWER PLANT

A Report of a Duty Test of the Gas Power Plant of the Norton Co., Worcester, Mass.

By G. I. ALDEN and J. R. BIBBINS

Members of the Society

The following report summarizes the tests conducted on Monday, Tuesday and Wednesday, June 24, 25 and 26, 1907, at the works of The Norton Company, on a complete producer gas power plant serving the works with light and power. This plant comprises, as its essential features, a 500 horse power Westinghouse horizontal, double acting gas engine with a 300 kilowatt direct connected direct current generator and a bituminous gas generating unit of the intermittent type and corresponding capacity, built by the Power and Mining Machinery Company. The test was purely a service run under the regular operating conditions prevailing at the plant, and with the power equipment in charge of the regular operating force. Load was, however, maintained during the night periods, 6:00 p.m. to 7:00 a.m., in order to shorten the test and eliminate the necessity of correcting for more or less intangible losses.

2 The test was executed conjointly by The Norton Company, under the general direction of Mr. Geo. I. Alden, and by The Westinghouse Machine Company, represented by Messrs. J. R. Bibbins and Daniel Armistead. In consequence of their general interest in the subject, The Power and Mining Machinery Company and the American Iron and Steel Company very kindly furnished skilled observers from their respective engineering staffs to assist in obtaining the required data. A complete schedule of observers is presented in the appendix, and acknowledgment is here tendered these gentlemen for

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

their efficient and painstaking assistance. Computations from the data secured were made by The Westinghouse Machine Company, as above represented, subject to subsequent revision and approval in the present final form, by The Norton Company.

OBJECTS OF TESTS

3 The principal object was to determine:

A The heat efficiency of the plant over a long continuous run at approximately full load.

Incidentally, other related data were readily available, and were accordingly included in the investigation.

B Heat efficiency of the gas engine at various loads.

C Mechanical efficiency of the gas engine.

D Water consumption of the gas engine.

E Oil consumption of the gas engine.

F Speed regulation.

G Thermal heat balance of the complete plant.

H Characteristics of gas produced, extent of variations in calorific value and analysis.

I In general, the normal operating qualities of the engine and the practicability of the complete producer gas plant for power purposes.

DIGEST OF RESULTS

a Full load test, 51 hours duration, continuous run without service interruptions of any kind; average load 11 per cent above generator rating, or practically full engine rating 332 kw., 483 b.h.p.

b Fractional load tests by the holder drop method; runs made at five different loads, from no load to full engine rating.

c A load of 600 h.p., sustained for a short time without abnormal drop in speed.

d Average coal consumption at the producer, 1.4 lb. per kw-hr., equivalent to 0.97 lb. per b.h.p. hr., using Clearfield bituminous run-of-mine, (14 321 B.t.u. per lb.).

e Average heat consumption at the engine, 10 100 B.t.u. per b.h.p. hr. at full load; 10 200 B.t.u. per b.h.p. hr. at average test load, equivalent to 25.29 per cent thermal efficiency at full rating.

f Mechanical efficiency, full rating, 83.8 per cent, average test load, 83.5 per cent.

g Average water consumption for engine only, 9.74 gal. per

b.h.p. hr. with 66 degrees fahr. inlet temperature and 47.1 degrees fahr. rise, equivalent to 9.4 gal. per b.h.p. hr. at full rating.

h Average cylinder oil consumption, 1.44 gal. per 24 hours, equivalent to 0.6 gal. per operating day, or 3.2 gal. per operating week.

i Speed regulation, no load to full load, 2.5 per cent above and below mean.

j Average producer efficiency, 74.4 per cent at full load; 73.8 per cent at average test load—both based upon lower or effective heat value of gas.

k Producer gas, average, 114.6 effective B.t.u. during 51-hour test; maximum variation 11.5 per cent above and below mean. Difference between total effective heat values—about $4\frac{3}{4}$ per cent.

4 Summarizing the general results: The test reveals a satisfactory attainment of results. Not only does the engine alone show good operating efficiency, but the plant as a whole, judged by standards of steam plant practice, using perhaps one-third of the coal required for steam power. The absence of interruptions from any cause points to a condition of general reliability sufficient for the character of service rendered. Especially is this the case, inasmuch as the power equipment was not put into prime condition for testing; so that the test represents a certain part of a normal week's run after six months' regular daily operation.

DISCUSSION OF RESULTS

5 Two independent tests were run for the purpose of providing data for segregating the efficiencies of the various parts of the plant; one, a 51-hour continuous load test to determine the coal, water and oil consumption, and the mechanical efficiency; the other, the holder drop series to determine the net heat consumption of the engine at various loads. The methods of conducting both series and observing all quantities are treated in detail in the appendix (and see general plan of test, Fig. 1.)

HOLDER DROP TESTS

6 This series is of particular interest, as it affords a measure of the engine efficiency at fractional loads *without independent adjustment* of detail parts for each load condition; that is, it represents the

efficiency occurring on regular shop load when fluctuating between the usual limits. Under the conditions, the holder drop method was the most convenient and accurate method of determining the efficiency characteristic, and in fact the only one by which the engine efficiency could be definitely segregated.

7 Table 1 summarizes the essential data for plotting Fig. 2. Here

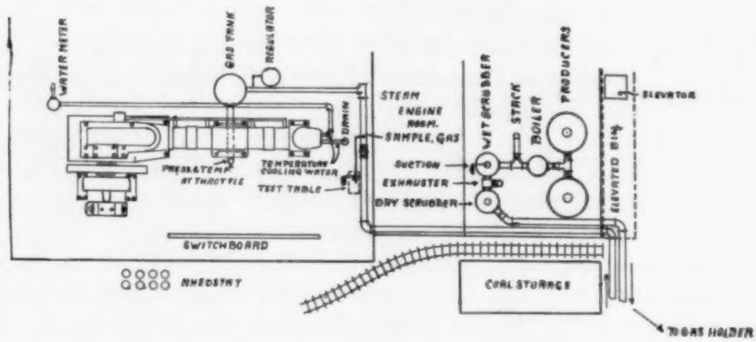


FIG. 1 ARRANGEMENT OF APPARATUS

TABLE NO. 1 HOLDER DROP TESTS

SUMMARY OF RESULTS

TEST NO.	A	B	C	D	E	REMARKS
Duration of run, min........	11	8	10	10	10	
Load; per cent eng. rating..		25.4	45.1	70.6	102.2	Circum. holder 110.33 ft.
Brake horse power.........		127.0	225.5	353.0	511.5	
Kilowatts..................		84.1	154.3	243.5	352.0	
Speed, revolutions per minute	158.00	156.0	154.0	152.0	150.0	Barom. = 29.26"
Holder drop, ft. per hr.....	16.91	24.96	32.22	39.80	51.00	Av. temp. of gas, 71.6 degrees fahr.
Cu. ft. per hr. 30" 60°.......	15 760.00	23 270.00	30 050.00	37 280.00	48 200.00	Av. gas pressure, $2\frac{3}{8}$ inches water.
Gas consumption rate: Cu. ft. per b.h.p. hr......	(Std. gas.)	183.2	133.2	105.5	94.25	Correction factor—0.9642
Cu. ft. per kw-hr............		276.8	194.8	153.1	137.0	
Heat value of gas: *a* Effective B.t.u. per cu. ft.	106.4	106.4	106.4	106.4	106.	*a* Av. of all tests.
B.t.u. per b.h.p. hr.........		19 480.00	14 160.00	11 215.00	10 030.00	
B.t.u. per kw-hr		29 430.00	20 720.00	16 280.00	14 560.00	
Thermal efficiency brake, per cent................		13.05	17.96	22.68	25.36	
Thermal efficiency (electrical) per cent...........		11.6	16.46	20.96	23.42	

the graphical method has been used to correlate results. The diagonal line, "cubic feet of gas per hr." represents the relative consumption at various loads, and more accurately than would an arithmetical average by proportion. From this line, the heat consumption line "B.t.u. per hour" is obtained. As it was impossible to take accurate calorimeter readings more rapidly than at 15 minute intervals, and as all of the holder drop tests were taken within a comparatively short period, an average heat value[1] of the gas was used, 106.4 B.t.u. (effective) per cubic foot at 62 degrees fahr. and 30 inches barometer. The curves, "B.t.u. per b.h.p. hr.," and "thermal efficiency," were obtained from the total heat consumption line

TABLE NO. 2 FRACTIONAL LOAD EFFICIENCIES

HOLDER DROP TESTS

NOMINAL LOAD		1/4	1/2	3/4	FULL	OVER-LOAD
Load, brake horse power		125.00	250.00	375.00	500.00	550.0
Gas cons.,[1] cu. ft. per b.h.p. hr.		190.00	127.00	105.6	95.00	92.20
Heat cons.,[1] B.t.u. per b.h.p. hr.		20 210.00	13 510.00	11 240.00	10 100.00	9 800.00
Heat cons.,[1] B.t.u. per kw. hr.		30 530.00	19 700.00	16 340.00	14 675.00	14 300.00
Heat cons.,[1] B.t.u. per i.h.p. hr.		11 180.00	10 600.00	9 050.00	8 460.00	8 295.00
Thermal efficiency per cent brake		12.58	18.84	21.66	25.21	25.97
Thermal efficiency, per cent elec.		11.16	17.32	20.9	23.25	23.85
Thermal efficiency, per cent indic		22.75	24.1	28.14	30.1	30.7
EQUIVALENT COAL CONSUMPTION[2] FOR VARIOUS PRODUCER EFFICIENCIES POUNDS PER UNIT HOUR						
Producer effic. per cent						
100 per cent	brake horse power hour.	1.413	0.944	0.785	0.705	0.685
	kilowatt hour	2.13	1.376	1.141	1.025	0.999
80 per cent	brake horse power hour.	1.766	1.181	0.980	0.882	0.857
	kilowatt hour	2.663	1.720	1.426	1.281	1.250
70 per cent	brake horse power hour.	2.015	1.347	1.120	1.006	0.977
	kilowatt hour	3.040	1.964	1.63	1.465	1.426

[1] Assuming same coal used on test—14 321 B.t.u.

[2] Standard Gas—106.4 B.t.u. (effective), 62 degrees 30 inches Hg.

with the aid of the generator efficiency curve Fig. 10, explained later. It will be noted that with full load on the engine, the efficiency approximates 10 100 B.t.u. per brake horse power hour and

[1] This heat value is considerably lower than the average during the 51-hour test, due largely to the condition of the fires. The holder tests were not run until after the long test had been completed; that is, after a continuous run at full load, of 51 hours equivalent to a week's regular shop load. However, the "low" gas made had no perceptible effect on the engine, except to require a slightly different mixture.

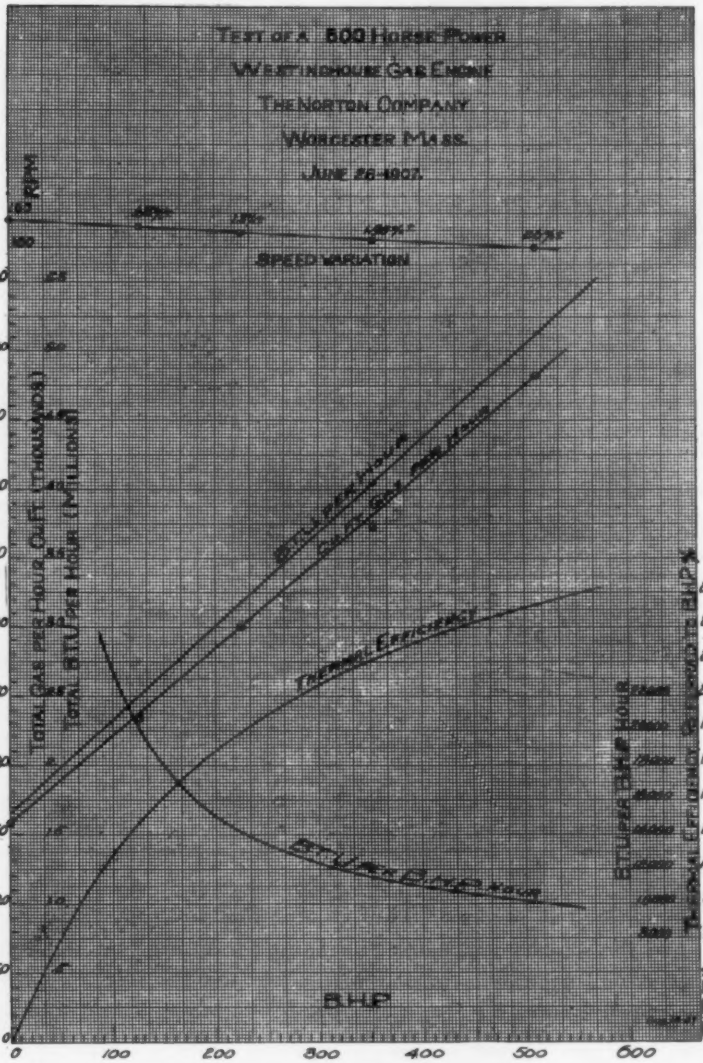


FIG. 2
TEST OF A 500 HORSE POWER WESTINGHOUSE GAS ENGINE

at a load of about 600 horse power, which was sustained for a few moments to test the rheostat, would be 9500 B.t.u. per brake horse power hour.

8 Table 2 presents data on heat consumption and efficiency at even engine ratings, interpolated from Fig. 2, from which it appears that the variations in heat consumption are well within normal limits imposed by present gas engine practice. Between three-fourths and over-load, which corresponds to the range in load generally experienced at the Norton plant, the heat consumption varied but 6¾ per cent from mean.

TABLE No. 3 51-HOUR TEST. SUMMARY OF RESULTS
NORTON CO., JUNE 24–26, 1907

	LOAD kilowatt	WATER cubic feet	OIL gallons	COAL[a] pounds
Quantity at finish	363 550.0	94 900.0	2.875	23 775
Quantity at start	345 710.0	63 560.0		[illegible]
Difference	16 840.0	31 340.0	2.875	23 775
Correction	+117.3			
Corrected difference	16 957.3	31 340.0	2.875	23 775
Elapsed time	51 hrs.	50 hrs.	48 hrs.	51 hrs.
Rate per hour	332.5	626.8	0.06	466[b]

	WATER cu. ft.	WATER gal.	OIL gallons	COAL pounds
Rate per kw-hr (332.5 kw.)	1.885	14.12	0.00018	1.402
Rate per b.h.p. hr (482.9 b.h.p.)	1.3	9.74	0.000125	0.965
Rate per i.h.p. hr (579.0 i.h.p.)	1.078	8.075	0.000104	0.805

[a] Clearfield run-of-mine—14 321 B.t.u. per pound as fired. Average thermal efficiency of plant, 18.43 per cent; engine, 24.93 per cent; producer, 73.81 per cent.

[b] See Appendix for discussion of relative condition of fuel bed before and after test and resulting heat correction.

Average gasification rate, 13.36 pounds per square foot per hour.

9 It is of interest in connection with the 51-hour test later treated, to compute the coal consumption equivalent to the heat consumption shown in these holder drop tests. This has been done in the table for various producer efficiencies. With a perfect producer, the engine coal consumption at full engine rating, would be about 1 pound per kilowatt hour; at 80 per cent efficiency, 1¼ pounds; and at an efficiency of 70 per cent, slightly under 1½ pounds, or nearly 1 pound per brake horse power hour.

10 The foregoing data are of course, based upon several tests at different loads, and one of the best indications of their relative accuracy, as well as of the general efficiency of the engine from a thermodynamic standpoint, is the fact that the total heat consumption line is straight, not curved (convex to the X-axis; in otherwords the losses, internal and external, are practically constant.[1]

11 It should be borne in mind that in these fractional load runs no attempt was made to vary the ignition point to suit the light loads and thus to obtain the most efficient card for each load. Here again tests results have been sacrificed to record actual operating conditions, and the curves truly represent the change in efficiency that would occur during rapidly changing loads on the plant.

12 The mechanical efficiency was determined from these tests, as well as from the 51-hour test. But as it was impracticable to change springs for the lighter loads, the cards at these loads carry a greater possibility of error. However, the results are quite consistent.

13 These holder drop tests show a mechanical efficiency of 83.6 per cent at a load of 483 brake horse power which corresponds to the average sustained during the 51-hour test, while the latter shows an average mechanical efficiency of 83.46 per cent (see Fig. 6). On a basis of indicated horse power the heat consumption of the engine works out 8460 B.t.u. per hour at full load, or a thermal efficiency in the cylinders of 30.1 per cent.

51-HOUR TEST

14 In order to eliminate the mass of observations which would otherwise be necessary to follow the operations during the long test, the principal quantities have been plotted in Sheets No. 3 and 4, the latter showing gas analyses and the general effect of varying water gas runs. All continuous quantities, as kilowatt output, water and coal, are plotted at a given time as the average for the preceding periods; hence, the brake horse power deduced from average kilowatt *should not necessarily coincide* with brake horse power deduced from instantaneous kilo volt ampere reading at the same hours. It is noteworthy, however, that the average of $\frac{1}{4}$ hour kilo volt ampere readings checked within 3.5 kilowatts with the average

[1] Thus, if the X-axis (load) were elevated to a point (Y = 1 650 000) on the Y-axis (heat) as shown in the sketch below; that is, neglecting fractional load losses, the *heat consumption is practically proportional to the load*, or 6800 B. t.u. per brake horse power hour, a *constant at all loads*.

TABLE NO. 4 51-HOUR TEST—6-HOUR AVERAGES CORRECTED DATA ONLY

PERIOD	JUNE 24, P.M.		A.M. JUNE 25 P.M.				A.M. JUNE 26 P.M.			TOTAL AVERAGE
	3–6	6–12	12–6	6–12	12–6	6–12	12–6	6–12	12–6	51 hours
Load										
Kw. by wattmeter	303.6	358.9	347.25	333.1	320.3	354.5	338.85	322.0	319.0	332.2
Kilo-volt-amperes	306.2	354.9	352.9	336.4	306.2	335.3	338.2	317.7	310.7	328.72
B.h.p. from kw	440.7	522.2	504.8	483.8	451.5	487.4	492.2	467.3	462.8	482.3
B.h.p. from k.v.a.	445.0	516.4	512.7	498.5	445.0	487.0	491.5	461.0	451.0	477.31
Amperes	1290.0	1412.0	1411.0	1382.0	1250.0	1341.0	1353.0	1302.0	1276.0	1335.2
Volts	237.3	251.1	250.1	243.5	245.0	250.0	250.0	244.0	243.3	246.03
Coal										
Lbs. fired per hour	443.5	454.7	455.3	466.00	475.0	463.8	449.7	522.0	452.0	466.0
Lbs. fired per sq. ft. per hour[1]	12.71	13.04	13.06	13.36	13.63	13.30	12.90	14.97	12.96	13.36
Water										
Cu. ft. per hour	613.3	594.1	613.3	595.3	592.6	653.1	652.0	651.0	677.0	626.8
Cu. ft. per kw-hr.	2.126	1.625	1.765	1.786	1.850	1.843	1.925	2.020	2.120	1.886
Gal. per b.h.p. hr.	10.43	8.53	9.100	9.200	9.260	10.04	9.270	10.44	10.95	9.740
Av. inlet temp.—deg. fahr.	65.00	65.50	65.00	65.40	66.30	67.00	66.00	66.60	67.30	66.01
Av. temp. rise—deg. fahr.	42.80	54.60	47.70	48.90	49.80	46.00	46.60	43.80	43.60	47.10
Gas										
Heat value by calorim.	112.3	109.16	108.0	116.7	119.4	113.5	111.8	119.3	120.9	114.56
Heat value by anal.		119.74	105.9	110.4	109.78	108.5	113.5	116.13	115.13	112.40
Heat value max.	123.2	122.60	122.1	125.8	125.6	117.1	116.3	122.8	126.0	126.00
Heat value min.	105.0	108.10	101.5	101.9	111.6	109.8	107.2	110.2	111.4	101.50

[1] Rate of gasification per square foot of fuel bed area of producers.
[2] Calorific values all reduced to effective at 62 deg. fahr. 30 inch Hg.

kilowatt recorded by the integrating wattmeters, 332.2 kilowatts. Similarly, the average gas analyses showed, within 2 B.t.u., the same calorific value as the average calorimeter readings—114.5 B.t.u. per cubic foot at 62 degrees fahr. and 30 inches barometer. These values are given in Table 3 and 4 summarizing the results of the 51-hour test. The latter gives the averages and total quantities for the entire period, the former the averages for the various six-hour periods.

15 From the general log, Fig. 3, it will be apparent that the load was maintained fairly uniform and as near rating as the fluctuations in the factory load would permit. During the night runs, it was possible to considerably exceed full rating; *e. g.*, on night shift, June 24, an average load of 522 brake horse power was carried for six hours—equivalent to nearly 20 per cent overload[1] on the generator with only 109 B.t.u. gas. The coal fired during the test, was fairly uniform in rate as shown by the log, Fig. 3, averaging 466 pounds per hour or 13.36 pounds per square foot of fuel bed area per hour. The calorific value of the gas was rather low during the night runs, but recovered during the day. This condition of affairs is largely attributable to the difference between the two producer men's methods of handling the fires. This low heat value did not, however, interfere in the least with the load which was heaviest when the gas ran as low as 104 B.t.u.

16 The water consumption naturally varied in inverse proportion to the temperature rise, as the inlet temperature was practically constant. No attempt was made to run the temperature of the jacket water to a very high point in order to increase the efficiency of the engine, but rather to maintain it at such a point as would best suit the load anticipated, as is the usual practice. The temperature rise could have been doubled without physical injury to the engine. In the gas log, Fig. 4, H and CH_4 are plotted to an increased scale in order to show the general effect of the length of the steaming period on the gas quality.

COAL CONSUMPTION

17 To facilitate the determination of the true amount of coal gasified during the 51-hour test, the fire was brought to the same

[1] During the noon hour Monday, while testing out the rheostat, a load slightly over 600 brake horse power was sustained by the engine for a few moments without indications of "stalling." This is equivalent to 20 per cent above the normal rating of the engine.

level and as near as possible to the same condition at the end as at the beginning of the run. Further, the test was not started until the fires had been subjected to normal rate of gasification for some time. A detailed discussion of the constitutents and relative heat value of the fuel bed before and after the test is taken up in the appendix and requires no further reference here.

18 The full load test was continued from Monday afternoon until Wednesday evening. A longer test would have undoubtedly been more desirable; but it should be borne in mind that the ordinary method of testing for periods of a week or more, usually followed out in the case of the continuous type of producer, could not be employed

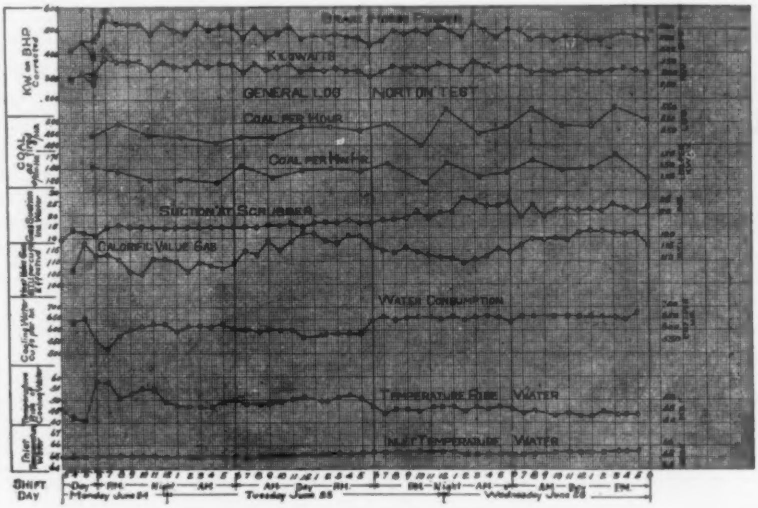


FIG. 3 GENERAL LOG NORTON TEST

here with the intermittent type, owing to the fact that the fires must be drawn at regular intervals for cleaning the producer. A normal week's run at this plant averages 54.4 hours (10-hour day). The test run of 51 hours is therefore, practically equivalent to a normal week's operation; or, in other words, practically equivalent to the period which occurs between regular shut-downs for the removal of ash and renovation of fires. Table 3 gives the weight of coal actually used during the test, 1.402 pounds per kilowatt hour. Table 5 gives the calorific value of the numerous samples tested.

MECHANICAL EFFICIENCY AND INDICATOR CARDS

19 Owing to the great labor involved in indicating the engine at sufficiently short intervals to follow the variations in load, it was decided to indicate at intervals of about one hour, with the precaution of taking electrical readings at *exactly* the same time. These simultaneous values could then be plotted and an average value struck, which would represent the average mechanical efficiency.

TABLE NO. 5 FUEL ANALYSES

SAMPLE	NO.	VOLATILE MATTER	FIXED CARBON	MOISTURE	ASH	B.T.U. PER LB.	
						DRY	ACTUAL
Clearfield bituminous[1] used during test	1	19.15	73.50	0.85	6.5	14 313	14 181
	2	20.12	73.60	1.09	5.19	14 531	14 360
	3	20.40	73.30	0.70	5.6	14 407	14 306
	4	18.30	75.40	0.90	5.4	14 484	14 347
	7	20.78	73.20	0.60	5.42	14 531	14 445
	10	20.75	71.81	0.75	6.69	14 345	14 236
	15	19.70	74.79	0.90	4.61	14 594	14 457
	18	19.30	76.40	1.00	3.30	14 641	14 486
	20	20.43	71.41	1.05	7.11	14 232	14 069
Avg. of 9 samples		19.87	73.71	0.87	5.54	14 450	14 321
Anthracite for building fires		5.20	78.95	3.20	12.65	12 709	12 320
Ash anthracite[2]			88.25	1.15	10.6	11 977	11 840
from under clinker			87.80	1.40	10.8	11 946	11 780
including ash in producer ash pits			88.30	0.70	11.0	11 946	11 850
Averages			88.12	1.08	10.8	11 956	11 823

[1] Sulphur in Clearfield Samples 2, 1.05 per cent; 10, 0.75 per cent; 20, 0.69 per cent; Average, 0.83 per cent.

[2] See section of producer bed, Fig. 13.

20 The results are shown in Fig. 6, covering 72 sets of cards taken regularly during the tests. This method of determining the characteristic of the engine is probably more accurate than taking three or four times the number of cards and averaging them. By the graphical method, unreasonably high or low values may be quickly recognized and allowed for in the average. Moreover, the reason for these high or low values may readily be traced back to some

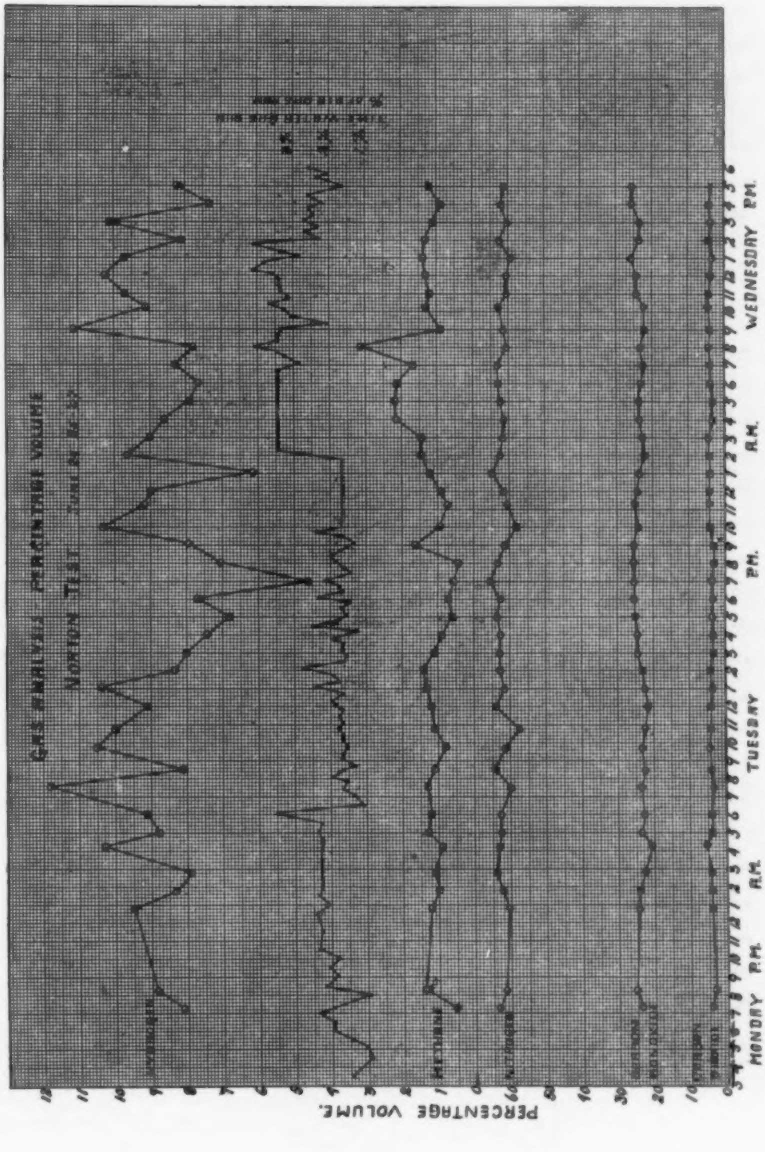


FIG. 4 GAS ANALYSIS PERCENTAGE VOLUME

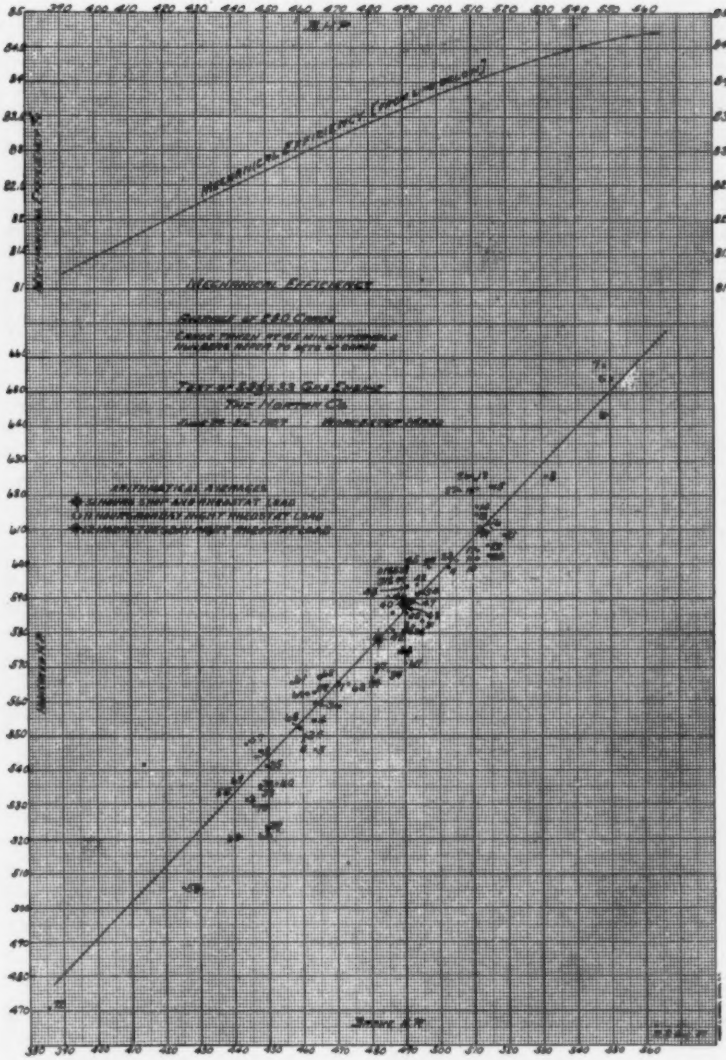
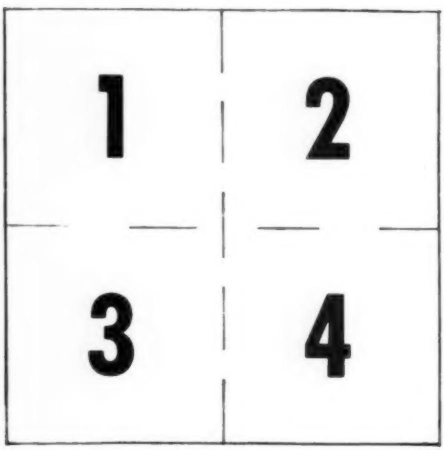
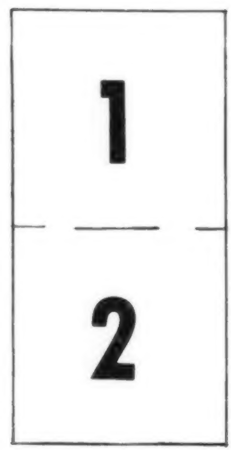


FIG. 5 TEST OF 23½ BY 33 GAS ENGINE

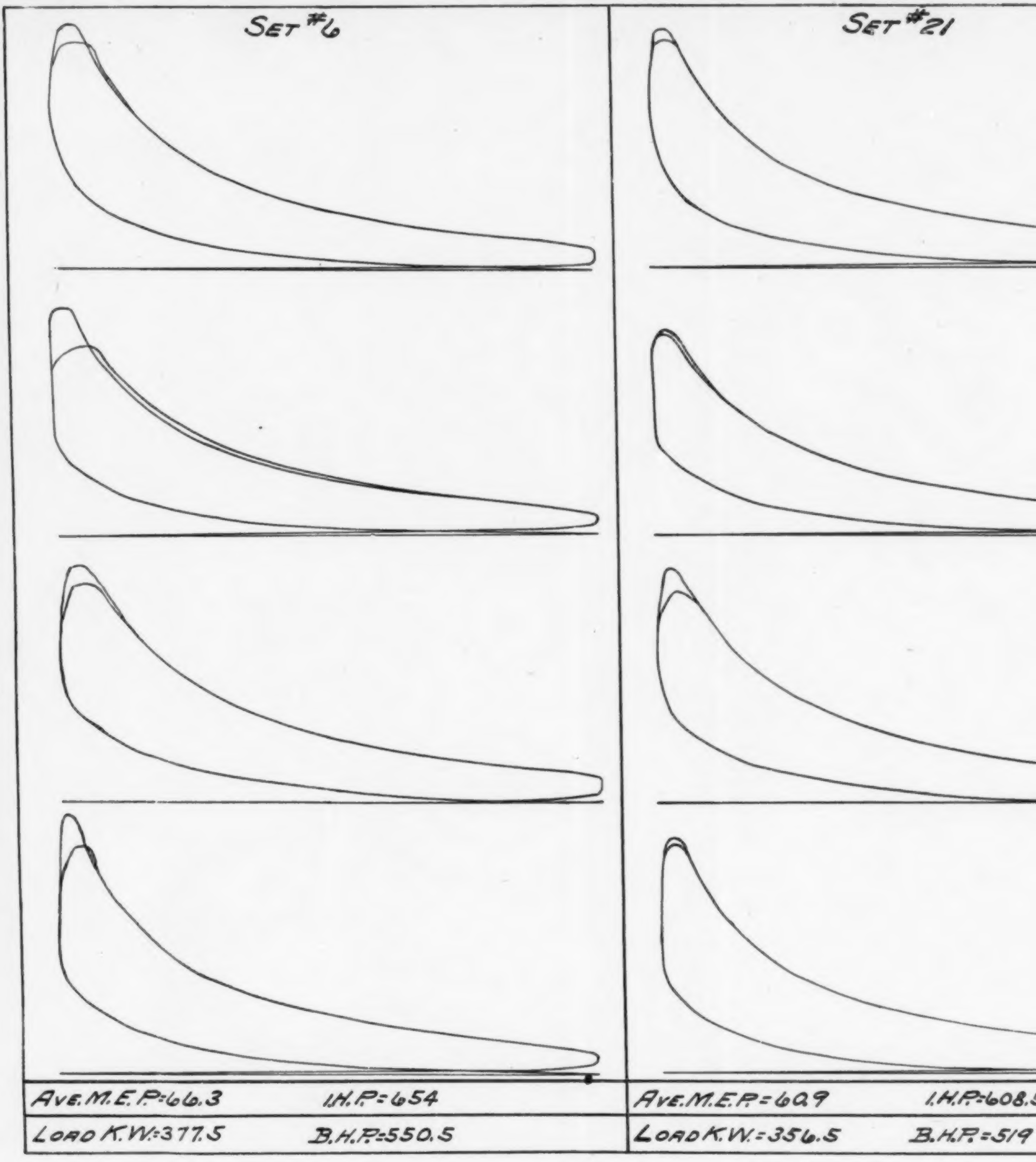
Maps on this order too large to be e
are filmed clockwise beginning in the
right and top to bottom as many fra
diagrams illustrate the method.





be entirely included in one exposure
in the upper left hand corner, left to
y frames as required. The following

1	2	3
4	5	6
7	8	9


SET #6
SET #21
AVE. M.E.P.=66.3
I.H.P.=654
LOAD K.W.=377.5
B.H.P.=550.5
AVE. M.E.P.=60.9
I.H.P.=608.
LOAD K.W.=356.5
B.H.P.=519

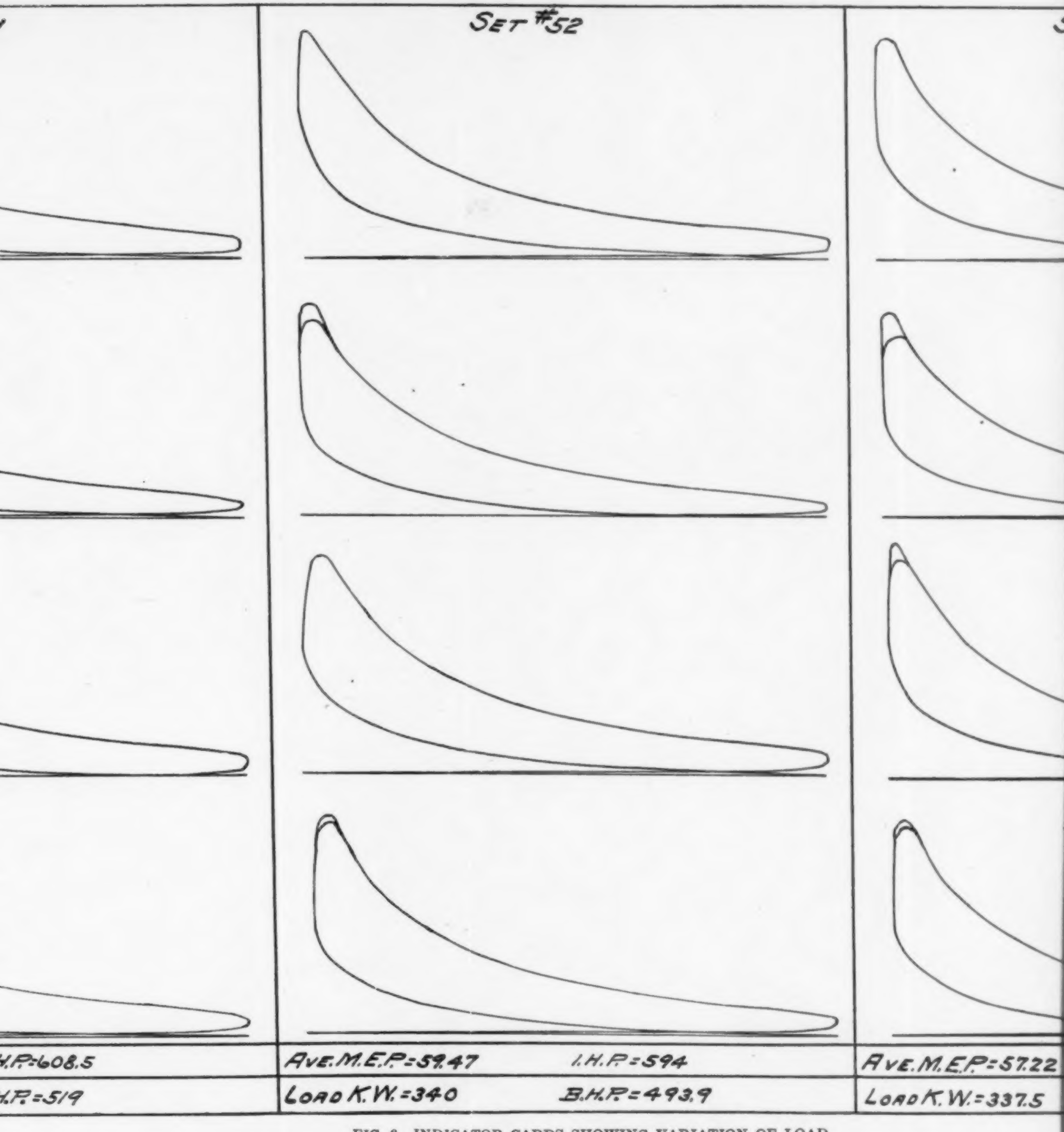


FIG. 6 INDICATOR CARDS SHOWING VARIATION OF LOAD

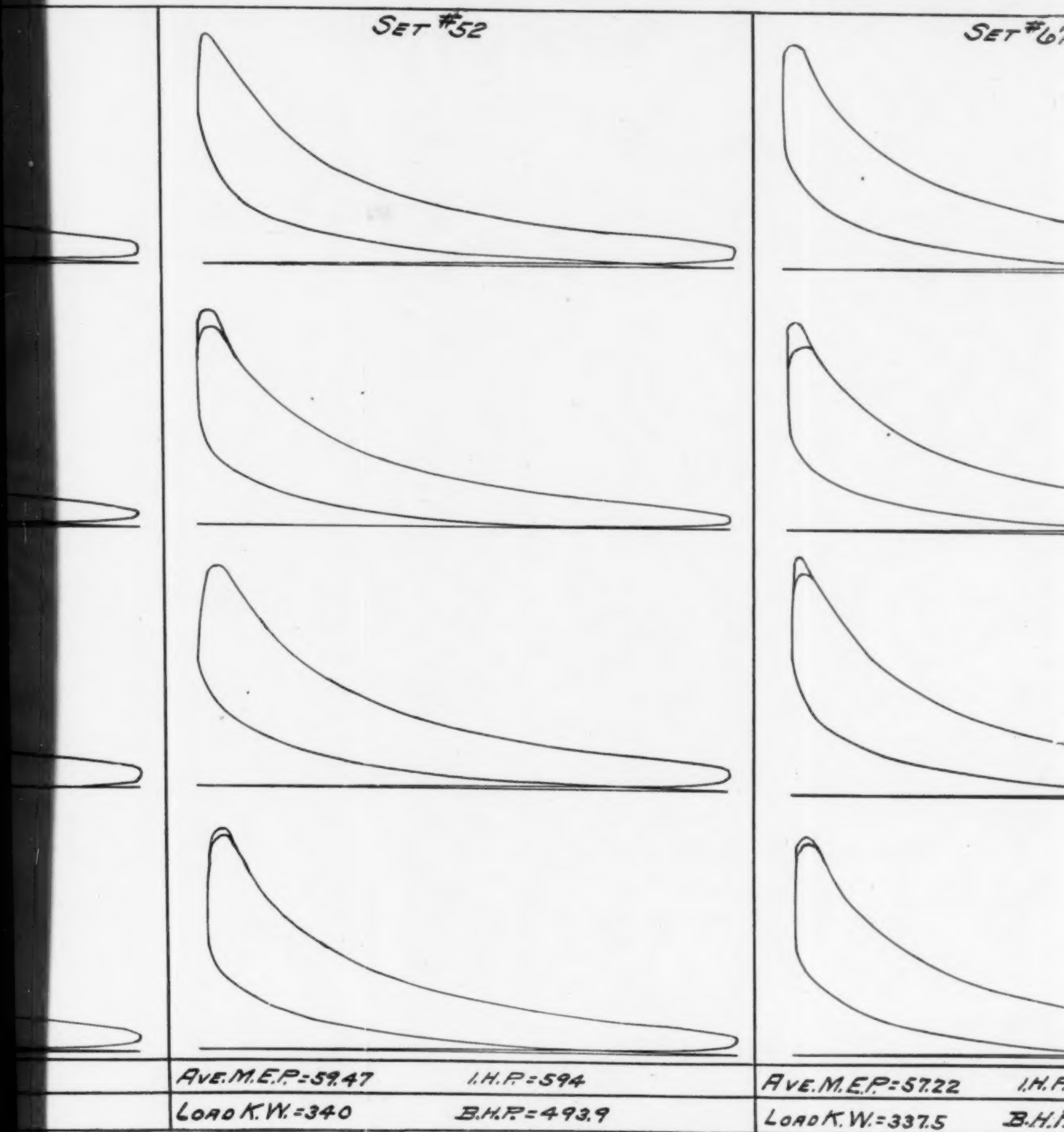
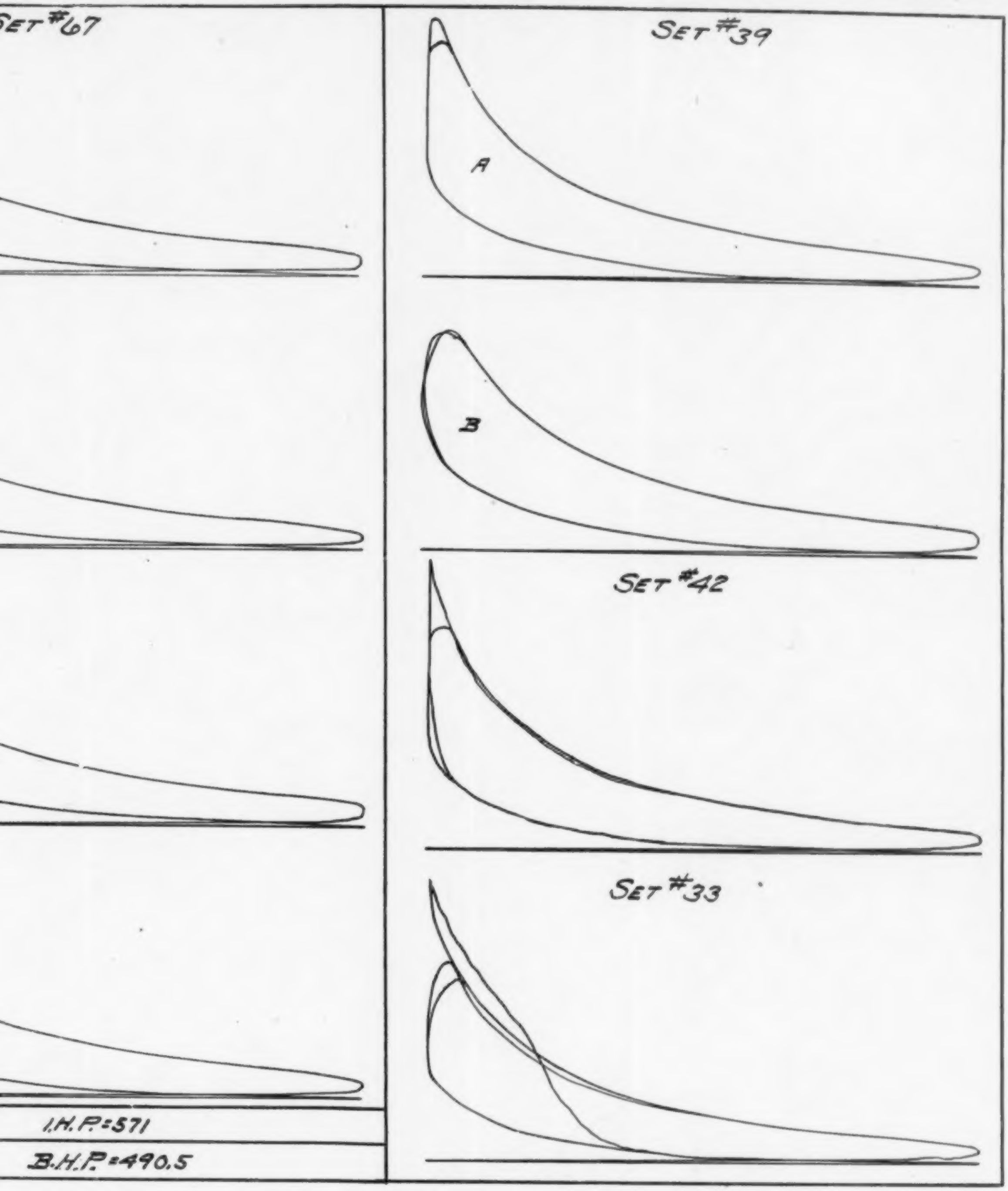


FIG. 6 INDICATOR CARDS SHOWING VARIATION OF LOAD


SET #67
SET #39
A
B
SET #42
SET #33
I.H.P.=571
B.H.P.=490.5

peculiarity of the card and allowed for; whereas, any error would probably not have been discovered by the method of averages.

21 To check this graphical method, however, three arithmetical averages are plotted on Fig. 5, the one x the average for the entire 51 hours, the others y and z, the averages for a period of 11 hours, beginning Monday evening, during which load was maintained practically constant by rheostat, and a similar period of 12 hours Tuesday

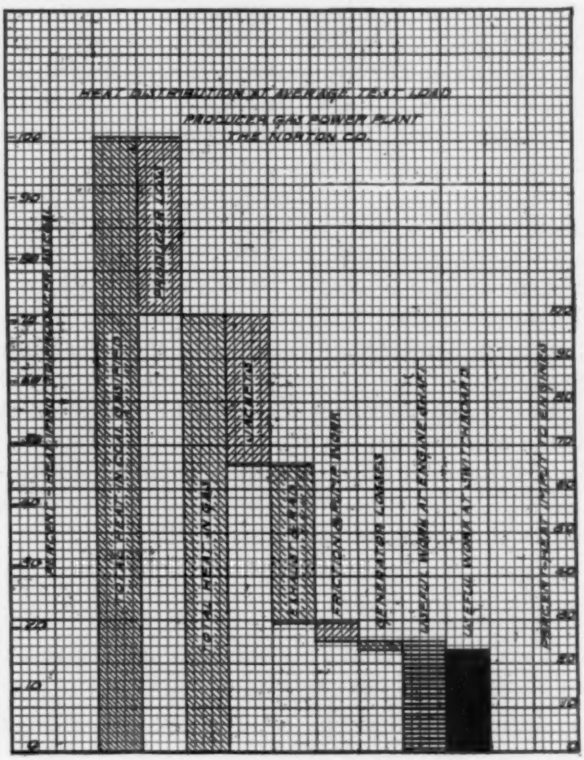


FIG. 7 HEAT DISTRIBUTION AT AVERAGE TEST LOAD

also on rheostat load. The fact that these points agree very closely with the curve, illustrates the reasonableness of the graphical method.

22 The average mechanical efficiency derived from Fig. 5 is at the average load carried, 83.5 per cent, or at full load, 83.8 per cent. Although here drawn to a large scale, the efficiency curve is very flat, lying between 83 and 84 per cent from 460 to 510 horse power. This efficiency includes, of course, all pump work.

23 For example, the sets of cards taken during the test are shown on Fig. 6. Slight differences are apparent between the several cards of each set, due to the lack of close, individual adjustment of igniters, which was not attempted, as the engine was tested in its normal condition. These cards show a mean effective pressure within the range of load carried, of from 55 to 65 pounds per square inch. For maximum loads, the mean effective pressure rose to 67 and 68 pounds. A study of the cards shows plainly that the "peaked" cards do not give the highest mean effective pressure. This is illustrated by the two cards from Set 39, *A* and *B*. Both are excellent cards, and of almost the same mean effective pressure, the fatter card, *B*, showing if anything, to better advantage. In the majority of cases, it appears that if the card loses its "peak" for any reason, the expansion line rises sufficiently to compensate therefor. Thus, in card 2, Set 6, the "flat" card shows 4 per cent higher mean effective pressure than the "peaked" card. Again, the "fat" card 42, gives 2.5 per cent higher mean effective pressure than the "peaked." This is further shown in extreme form in card 33, which traces a "premature."

24 "Prematures" and backfires occurred at various times during the test, sometimes rather frequently, but mostly at intervals of several hours, none of which appeared to affect the operation of the engine. In regard to these, there seemed to exist throughout the test a definite relation between the occurrence of backfires and the charging of fresh fuel in large quantities, apparently indicating the presence of rich hydrocarbon volatiles, which it was impossible to segregate with the analytical apparatus available.

HEAT BALANCE

25 From the various quantities observed and derived, it is now possible to obtain partial heat balance of the complete plant at the

TABLE NO. 6 DISTRIBUTION OF HEAT AT AVERAGE LOAD

	ENGINE ONLY		ENTIRE PLANT	
	Brake	Elec.	Brake	Elec.
Useful work	24.9	22.98	18.38	16.97
Electrical losses		1.92		1.41
Friction and pump work	4.58	4.58	3.37	3.37
Jacket absorption	34.22	34.22	25.22	25.22
Exhaust and radiation (by bal.)	36.3	36.3	26.81	26.81
Loss in producer			26.22	26.22
	100.00	100.00	100.00	100.00

average test load, 483 brake horse power. Knowing the useful work, jacket absorption, mechanical efficiency, electrical losses and producer losses, the remainder may be assigned to exhaust and radiation, as there are no losses of any magnitude in the producer gas system corresponding, for instance, to condensation and leakage

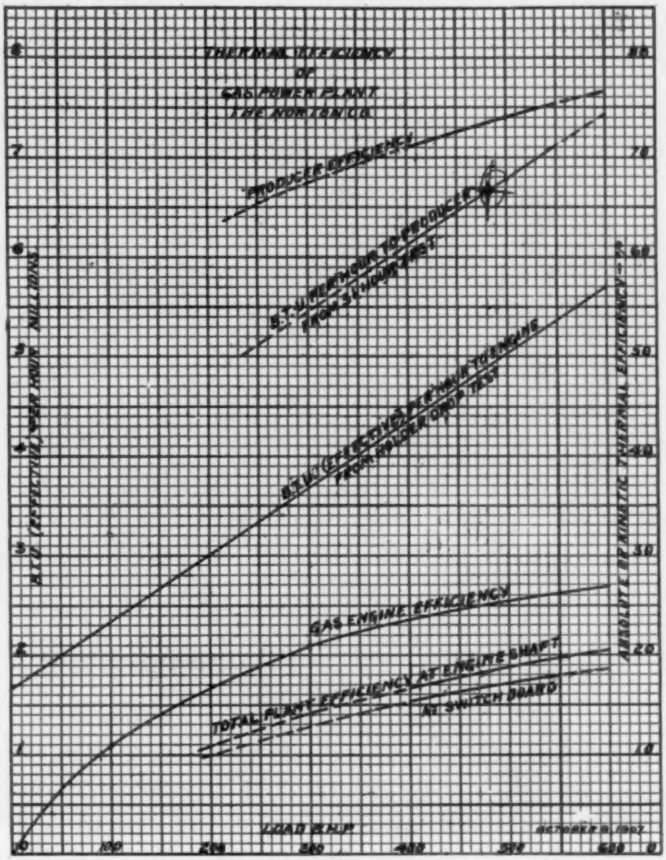


FIG. 8 THERMAL EFFICIENCY OF GAS POWER PLANT

in a high pressure steam system. This heat balance is given in Table 6, and in graphical form in Fig. 7. This balance shows that practically one-fourth of the heat delivered to the engine by the producer is converted into useful work at the engine shaft, or 23 per cent at the generator terminals. It also shows a moderate jacket absorption, considering the small temperature rise. It should not be

inferred that with higher water temperatures the relative percentage of jacket absorbtion and exhaust will reverse. It has been shown by experiment on both small and large engines that the decrease in

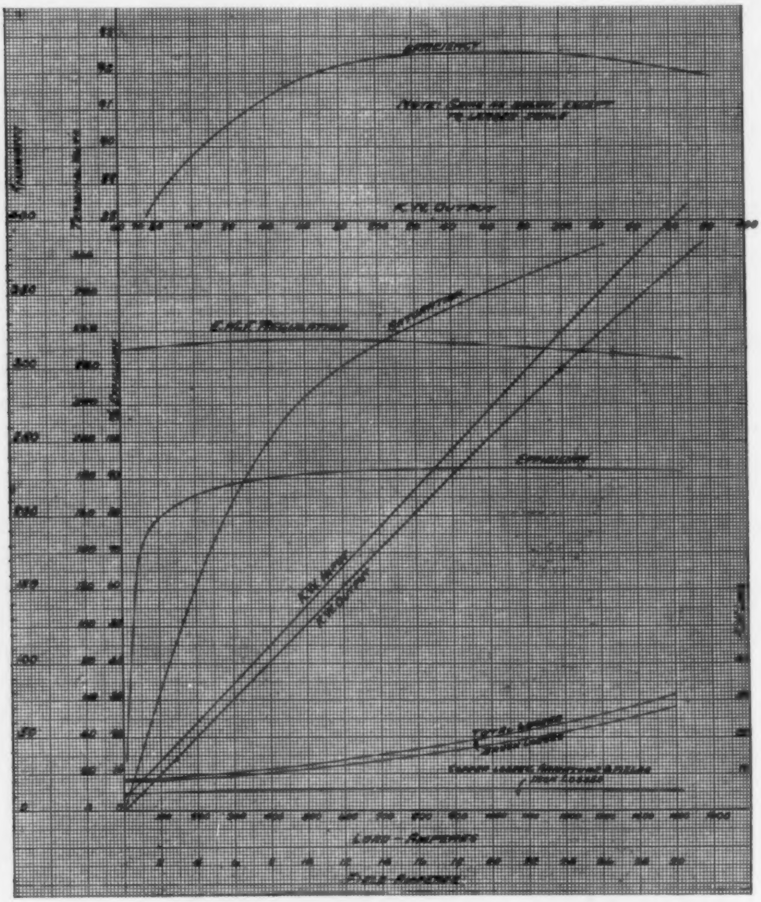


FIG. 9 GENERATOR TEST RECORD
300 KW. 250 VOLT DIRECT CURRENT COMPOUND WOUND GENERATOR

jacket absorbtion very largely appears as increased work and hence increased efficiency.

PRODUCER AND PLANT EFFICIENCY

26 Upon the basis of the above heat balance the segregated efficiencies of the principal parts of the plant over the range of load

carried in its normal operation may be determined, with a single assumption—that the losses in the producer bear a constant relation to the weight of coal fed into the producer; that is, to the heat input. This has been worked out on Fig. 8, and for the short range in loading from 400 to 550 brake horse power, it is believed the assumption is reasonable.

27 Starting with the total heat consumption line of the engine, as determined from the holder drop tests, the corresponding total

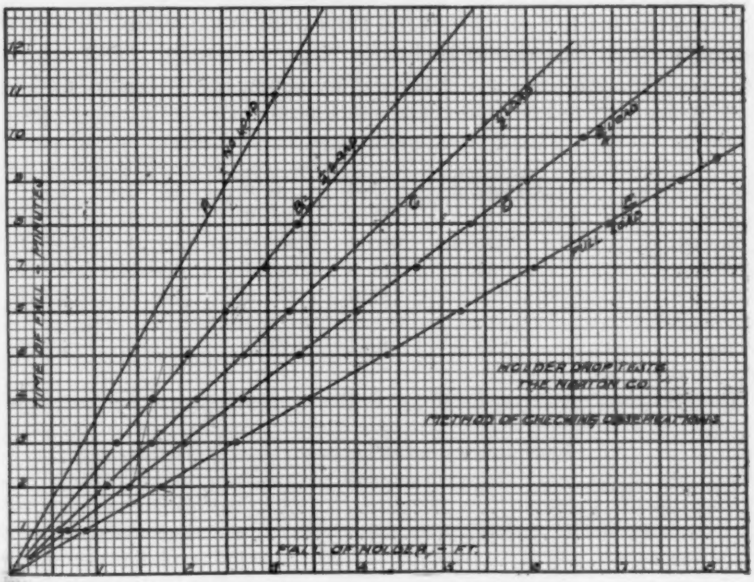


FIG. 10 HOLDER DROP TEST
METHOD OF CHECKING OBSERVATIONS

heat consumption of the plant, in the form of coal fed into the producer, may be represented by a parallel line. From these two total heat lines, the thermal efficiency curve of the plant, engine and producer, are respectively derived. At full load, the complete plant turns 18.5 per cent of the heat in the fuel into work at the shaft, or 17.1 per cent at the switchboard; and at this load the producer efficiency is 74.1 per cent, as compared to 73.8 per cent average for the 51-hour test.

GAS CHARACTERISTICS

28 The variations in gas from time to time are shown in Fig. 4 only as averages for hourly periods. Table 4 gives corresponding

maxima and minima for six-hour periods. Thus, the extreme limits of variation during the test range from 101 to 126 B.t.u. (effective) per cubic foot, or 10 per cent above and 11 per cent below the mean value for the entire test.

29 The relative effect of water gas and air gas runs is shown in the gas log Fig. 4. Although the hydrogen at the engine is not instantaneously responsive to an increase in water gas, yet in general the average hydrogen content follows the percentage water gas quite perceptibly. Most of the water gas runs continued for 30 seconds, though toward the end 20-second runs were made at short intervals, resulting in an increase in H, but to 11 per cent only. This suggests the possibility of improving the gas by short, heavy blasts, and correspondingly brief periods of steaming; provided, of course, there is sufficient holder capacity to absorb the variations in gas production.

TABLE NO. 7 SPEED VARIATION TESTS

Speed, r.p.m.	155	154.0	152.0	150.0	149.0	148.0
Volts	255	255.0	257.0	258.0	258.0	257.0
Amperes		327.5	665.0	955.0	1303.0	1347.0
Kw		86.1	170.8	246.6	336.1	346.0
B.h.p.		129.6	247.6	356.5	489.3	503.0
Per cent full rating		25.9	49.5	71.2	97.9	100.5
Speed drop, per cent ± mean		0.819	0.958	1.597	1.916	2.236

Instantaneous Load Test June 27, 1907, 6 p.m.

No-load to full-load, 280 volts, 1190 amperes, 345 kilowatts, 502 brake horse power.

No-load speed	155 revolutions per minute.
Load thrown on	148 revolutions per minute.
Load thrown off	155 revolutions per minute.
Difference	7 revolutions per minute.
Speed variation	4.6 per cent of total − 2.3 per cent ± mean speed.

30 CO_2 records, were taken to follow any changes in the gas that could not be caught by hourly analyses. During the time the apparatus was in action the variations were small, agreeing quite closely with the analyses. The CO_2 record gave a rough indication of the condition of the fire, and showed an abnormal percentage of CO_2 with excessive air supply drawn in during the period of blast.

31 The measurements of dust, or suspended matter, showed a large reduction of total impurities between wet scrubber outlet and engine. It is quite apparent from the appearance of these samples that a large proportion of the lampblack passing the wet scrubber

finds its way to the engine in spite of the dry scrubber and the opportunity for settling in the holder, but without deleterious effect on either the operation or efficiency of the engine.

SPEED REGULATION

32 Three independent observations give data on speed regulation:

a Speed during holder drop tests, Fig. 2.

b Speed variation tests at various loads, Table 7.

c Instantaneous speed variation test, also Table 7.

These agree closely, although taken on different days. Thus, at full engine load, the drop in speed from no load to full load, was: *a* 2.6 per cent, *b* 2.24 per cent, *c* 2.3 per cent. Fig. 2 shows the speed characteristics practically a straight line without any drooping tendency at the heavier loads. This indicates a good margin of overload capacity.

GENERATOR TESTS

33 Owing to the existence of detailed records of tests on the generator at the builder's works, these were adopted with the precaution of checking same by independent recalculation of efficiency, not only at rated voltage, but also at 240 and 230 volts. These efficiencies include iron and copper losses (in armature and field, both series and shunt) and brush losses (I^2R + friction). As the generator was proportioned so as to give maximum efficiency at average shop load (270 to 310 kw.), the efficiency during the 51-hour test was somewhat lower, 92.3 per cent, an entirely reasonable figure for a machine of this size.

34 Temperature rise was recorded by the thermometer applied to the shunt field coil. The maximum observed was 167 degrees fahr. with room temperature 92.5 degrees fahr., giving a rise of 74.5 degrees fahr., or 41.4 degrees cent. During the preceding three hours, the generator sustained a load of from 365 to 375 kilowatts (25 per cent above rating) immediately following several hours run at full load. This rise is not abnormal, considering the high engine room temperature, for which reason the average load during the test was carried somewhat lower than would have been the case during cooler weather.

APPENDIX

METHODS OF TESTING

35 As the Norton plant regularly operates only ten hours per day from 7:00 a.m. to 12:00, and 1:00 p.m. to 6:00 p.m., it was decided to maintain the plant at full load during the normal standby period. Otherwise the intangible effect of standby losses would interfere to a considerable degree with the accuracy of the net operating results desired.

LOAD

36 Load control was secured by means of a water rheostat especially constructed for the purpose, and possessing sufficient flexibility to bring the average shop load up to approximately full rating, and at night to maintain the full load. This method, and the particular type of rheostat used proved very successful. During the night, an almost constant load could be maintained. During the day, however, it was impossible to operate at so high an average load, owing to the fluctuations from shop motors, which, in addition to the rheostat load, would otherwise overload the plant. Furthermore, the excessive atmospheric temperature, 90 to 96 degrees fahr. in the engine room, during the period covered by the test, made it undesirable especially during the day to carry heavier load. At times, when the shop load was fairly quiescent, the rheostat was used to bring it up to the desired average.

SIGNALING

37 Signaling was accomplished by means of an electric bell, with repeaters in the producer room and outside at the gas holder. A five-minute "attention" signal brought the various observers to their places. Observations commenced at the five-second "preparatory" signal and were recorded after the "final" signal. This method proved to be especially valuable during the holder drop tests, as all observers were simultaneously apprized of the other's movements, which eliminated the necessity of synchronizing watches.

FREQUENCY OF READINGS

38 At 15-minute intervals ammeter, voltmeter, gas calorimeter; 30-minute intervals—scrubber suction and water gas runs; 45-minute intervals—indicators, wattmeters, watermeters, temperatures, ba-

rometer, pressures and speeds; 60-minute intervals—gas analyses; every two hours—coal weights, as required.

OUTPUT

39 Electrical instruments were used entirely to measure output. Switchboard ammeter, integrating wattmeter and standard Weston voltmeter readings were simultaneously observed for an independent

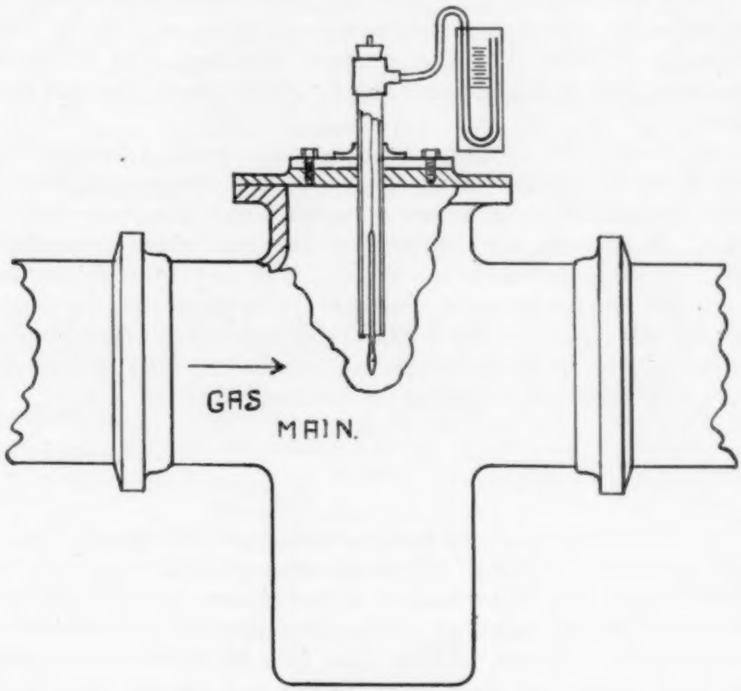


FIG. 11
APPARATUS FOR MEASURING GAS PRESSURE AND TEMPERATURE

check. The load meters were calibrated at the close of the test by means of a standard Weston shunt and mill-voltmeter, showing a uniform calibration error.

BRAKE HORSE POWER

40 In all cases, the brake horse power was calculated from kilowatt readings showing by the generator efficiency curve, Fig. 9, which is based upon the efficiency tests formerly made on this par-

ticular machine. The distribution of losses, however, was again checked at various loads and substantially agreed with the curve.

INDICATED HORSE POWER

41 Indicated horse power was determined by four indicators of the outside-spring type, manipulated simultaneously at the given signal. The preparatory interval of five seconds was allowed for opening indicator cocks, so that very little opportunity existed for gumming of indicators, which were carefully cleaned several times during each shift. Electrical readings were also taken at exactly the same time so that no opportunity should exist for a change of load.

42 In order to obtain more representative cards, two cards were traced *before lifting the pencil.* They were then integrated separately, and averaged, if any difference appeared, which was quite often the case. In all cases, the atmospheric line was traced *immediately after* the card was taken—not before. This precaution is intended to compensate for the slight expansion taking place when the indicator was being heated. The indicator rigging was a permanent fixture of the engine. With the lost motion absorbed by the strong spring, very little opportunity existed for distortion of cards.

SPEED

43 Speed was measured both by tachometer and speed counter. The tachometer, a Schaeffer-Budenberg centrifugal instrument, was belted to the main engine shaft so as to be close to the last observer of the indicators, who noted the instantaneous speed immediately after releasing the indicator. At the same time the speed was counted from the engine lay shaft by the signal man, so that very little opportunity occurred for change. These observations checked closely.

TEMPERATURES

44 Temperatures were determined by ordinary chemical thermometers, checked in hot and cold water baths for accuracy. As all of the temperature measurements, excepting calorimeter temperatures involved inappreciable errors, considering the character of results desired, no attempt at extreme accuracy was made in the thermometry of the test.

PRESSURES

45 Gages of the U-tube, or manometer type, were installed at the engine throttle, gas supply-line and holder, Fig. 1. Except for cyclical fluctuations, due to engine suction, the pressure was practically constant at all points, owing to the uniform weight of the holder. Barometric pressure was read by vernier in the engine room, and checked by Weather Bureau observations reduced to proper level. In the final results, all gas readings have been reduced[1] to standard conditions, 62 degrees fahr. and 30 inches barometer, taking also into account the excess pressure above atmosphere, shown by the several manometers. These reductions were necessary before consistent results could be expected in the gas consumption line, Fig. 2, as gas came to the engine unusually hot 92 degrees fahr. during the day. The lower or effective heat value has been used in all cases, as explained elsewhere.

GAS SAMPLING

46 Gas sampling was done as close to the engine as convenient, not more than 25 feet of piping intervening between the point of sampling and the throttle. See Fig. 1. Moreover, the samples were drawn from the center of the main by means of an extension tube. A standard Junker calorimeter was employed with thermometers indicating to 0.01 degrees cent. with close reading lens. For analysis, a modified Orsat, or Hempel, apparatus was employed with explosion bulb for H and CH_4. In addition, an "Ados" automatic CO_2 recording apparatus was in operation during the entire time.

COOLING WATER

47 Jacket water was measured by a Keystone meter. Being practically a new meter, its possibility of error was not taken into consideration, especially as the resulting data were only incidental to the test. Care was taken to observe the temperatures of engine inlet and overflow water sufficiently close to the engine to avoid any appreciable radiation loss. As it was impossible to measure the temperature and quantity of each hot water outlet at the engine, the outlet thermometer was so located in the discharge main as to insure

[1] McFarland's "Reduction Factor for Gases."

a thorough mixing of several hot water outlets from pistons and jackets before reaching the thermometer, Fig. 1.

HOLDER DROP TESTS

48 The method employed during the holder drop tests was based upon the observations of the *rate of fall* of the holder with the gas supply from the producer *entirely shut off* and the engine running at a definite load. Previous to each test, the engine was maintained at its load for ten minutes or more, and at a given signal, the producer was cut off by valves, electrical readings taken and the fall of the holder measured by tape and stop watch. Observations were not begun until the holder had fallen an inch or two and attained a definite rate. The stop watch was then set as the index passed a given division and the readings were recorded at ten-second intervals until the release signal. These readings were then plotted to time and fall, which gave at once a visual indication of the correctness of the readings, not to be attained by using simply the first and last readings of the tape.

49 It is obvious, that the slightest irregularity in the fall of the holder due to sticking along the ways, or unequal depression from any cause would easily have been detected by observations falling irregularly on the plot. This graphical method also shows at a glance whether the gas consumption of the engine at a constant load, is uniform within short intervals of time.

50 Fig. 12 shows also the method of measuring the temperature and pressure at the holder. At the position shown, there could be no question as to the accuracy of the temperature measurement. Even in lifting out the thermometer for reading the rush of gas practically eliminated the cooling effect of the pipe walls. Owing to the effect which the heat of the sun would have on the dimension of the holder, the holder drop tests were made after sundown with a strong wind blowing, which served to perfectly equalize the atmospheric temperature.

51 A decisive check on the holder drop series is offered by the close agreement with the theroetically straight line relation, Fig. 2, of all the points representing total gas per hour at various test loads. Although each test lasted but a few minutes, from 8 to 11, yet the determination of the rate of fall by this method is fully as accurate as for the fall of a holder of twice the capacity observed for a period twice as long.

52 Furthermore, the effect of any possible error in reading the tape is certainly negligible. Thus assuming an error of one inch, in

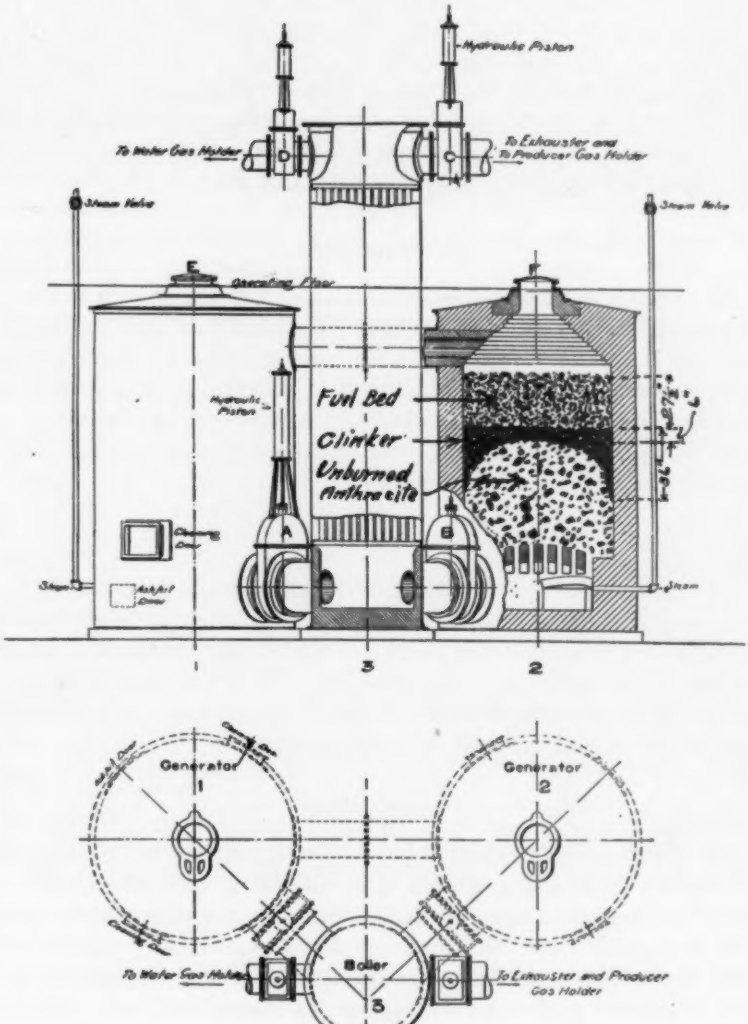


FIG. 12 SKETCH OF PRODUCERS AND FUEL BED

the measurement, which is entirely out of the question, if analyzed graphically as above, this would represent but 1 per cent of the gas consumption at full load, as the total fall corresponding was about 100 inches. Another point to be considered is that leakage in gas during the holder drop runs, due to lack of tightness of valves in the producer house, results in more gas being charged to the engine than used, as the leakage from the main which is under pressure would escape to the purge stack through the leaky valves.

OIL CONSUMPTION

53 Owing to the continuous circulating filtering system in use at the plant, no perceptible amount of engine oil was used during the test, all the drains from the journals being returned to the supply system. At the beginning of the test cylinder oil pumps were filled, and the level noted on gage glasses. At the end of the test, they were filled to the same level by a measured quantity of oil, which showed the entire quantity used.

DUST DETERMINATION

54 Samples of gas, delivered to the engine, and from wet scrubber, were examined for dust. For this purpose, a tube containing loose cotton was used, the weight of which was determined before and after the passing of a measured quantity of gas (five cubic feet), the difference being the accumulation of impurities. This tube was heated before and after to drive off moisture.

COAL SAMPLING

55 From each 1200 pound batch of coal weighed out at intervals of about two hours, a sample of about 100 pounds was quartered down and preserved in a glass can. Similarly, a sample of the anthracite from which the new producer fire was originally started was preserved. When the fires were drawn at the end of the test extreme care was taken to obtain a fair sample of the so called "ash" removed from beneath the clinker zone. Three separate samples were taken and quartered down from a full barrow. A Parr calorimeter was used for the determination of heat values.

COAL CONSUMPTION

56 In regard to the precise method of conducting producer gas tests of this kind, involving coal consumption, opinions seem to

differ widely, particularly as to the method of assigning "debits" and "credits" for varying conditions of fuel bed before and after the test. It was the original idea to equate the conditions as far as possible at the beginning and end of the test, as would be the case in testing a continuous type producer; that is, to make a "flying start" and end in a similar manner, so that the actual amount of coal fired would be the correct amount chargeable to the test. But with the present practice of week-end cleanings of the producer fires employed in the intermittent type of plant, the test was necessarily started with producers practically full of "green" fuel, largely anthracite, with a topping of bituminous.

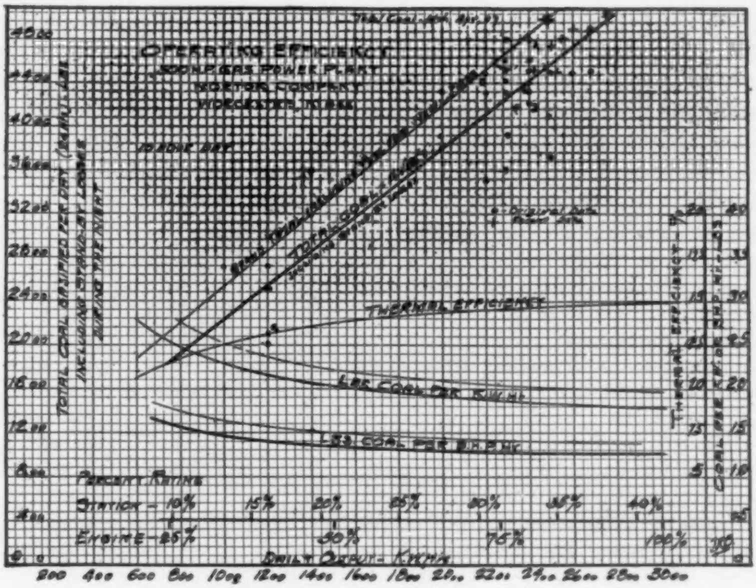


FIG. 13 OPERATING EFFICIENCY 500 H. P. GAS POWER PLANT

57 At the end of the test, midnight Wednesday, it was expected that this original fuel bed had depreciated in value, but when the fires were partly cleaned on the next night, Thursday, the majority of this anthracite was found still in the producer in the form of good combustible of practically the *same* heat value as the original anthracite. Analyses of this "ash" are given in Table 5. These analyses showed 10 per cent higher carbon content than the original coal. The obvious inference is that the anthracite bed operated as a filter for the bituminous bed above, from which carbon was

actually deposited rather than dissipated during the descent of the hydro-carbon gases.

58 A careful survey of the fuel bed Wednesday night, immediately after the close of the test, showed conditions approximated by Fig. 13, which applied to both producers. The upper "ash" (clinker line) was found definitely located, practically flat and at the same level in both producers on the average 27½ inches below the top of the fire. The original anthracite bed had shrunk about 25 per cent in volume and 40 per cent in weight.

59 Assuming now that a fuel correction is necessary, if the test is to be charged with all of the coal originally fired, it must also be credited with the combustible remaining in the producer at the close of the test. To this end it is assumed that the 27½ inches of fire bed varies uniformly in combustible from fresh "green" coal at the top, to ash at the bottom; that is, it is equivalent to half of good fresh coal of full heat value. This refers only to that part of the bed lying above the clinker line. Crediting the test with this salvage

TABLE NO. 8 NORMAL OPERATING ECONOMY
NORTON GAS POWER PLANT
AVERAGE FOR NINE WEEKS ENDING APRIL 21, 1907

Number of hours per week run on load	54.4	hours.
Output	13 500.0	kw-hrs.
Average running load	248.1	kw.
Average running load per cent rating of engine	72.2	per cent
Coal gasified (including standby losses)	24 839.0	pounds
Coal for new fires	2 369.0	pounds
Coal for new fires (per cent of producer coal)	9.5	per cent
Total coal for all purposes	27 204.0	pounds
Avg. total coal per hour including new fires	500.00	pounds
Coal consumed (excluding new fires) per kw-hr	1.83	pounds
Total coal consumed per kw	2.015	pounds

value of the remaining fuel bed, and the proper thermal shrinkage in the anthracite originally fired, the net charge works out to a debit against the test of 998 pounds of bituminous coal which may be considered as a correction to the amount actually fired. This results in a coal consumption for the entire plant of 1.006 pounds per brake horse power hour, as compared to 0.965 pounds per brake horse power hour based upon the coal actually fired, and a producer efficiency of 70.87 per cent.

60 It will be noted from the above that the point at issue involves a comparatively small correction. Even admitting an error of 25 per cent in the valuation of the remaining fuel bed, the resulting

error is but 1.85 per cent of the total, which is inconsiderable under the circumstances. Two factors, however, tend to justify discarding this correction: first, that the producer was not "starved" of fuel toward the end of the test in fact, quite the contrary, as is shown by the log, Fig. 3; second, that as fuel was fired in small quantities every five or ten minutes no appreciable error in the weight actually charged would be incurred either the one way or the other.

61 That the actual results recorded in this paper are quite reasonable is clearly demonstrated by the results that are being obtained in the normal operation of the plant, shown in Table 8, which summarizes a period of nine weeks ending April 21, 1907. While the average load was but 72 per cent of the engine rating, the coal consumed during the week, including 14 hours daily standby loss, averaged but 1.83 pounds per kilowatt hour, or, including the fuel required for rebuilding fires on Sunday, 2 pounds per kilowatt hour. In Fig. 14 these operating data are analyzed for various loadings occurring during the period covered. From this it appears that the plant would require 1.78 pounds per kilowatt hour during weekly operation, out of which the plant is idle nearly three-fifths of the time. This agrees closely with the results of the Gould Coupler gas power plant, presented before the Society in December, 1906.

PERSONNEL OF TEST

The Norton Co.

Mr. Geo. I. Alden, director.
Mr. D. L. Gallup, assisting.
Mr. Daniel Armistead, general charge of observers.
Mr. J. R. Bibbins, general charge of test.

OPERATION.	DAY	NIGHT
Indicator 1	Mr. Bibbins	Mr. Day.
Indicator 2	Mr. Bradley	Mr. Day.
Indicator 3	Mr. Hill	Mr. Leland.
Indicator 4	Mr. Bisson	Mr. Dodge.
Switchboard	Mr. Mudgett	Mr. Stevenson.
Calorimeter	Mr. Phelps	Mr. Burke.
Analyses	Mr. Von Sholly	Mr. Griffin.
Coal	Mr. Keith	Mr. Johnson.
Water Consumption	Mr. Bibbins	Mr. Day.
Temperatures and Pressures	Mr. Armistead	Mr. Day.

General Assistant .... Mr. Chapman.
General Assistant .... Mr. Morden.

Calibration of electrical instruments	Messrs. Fick and Mudgett.
Holder drop, pressure and temperature	Messrs. Bibbins and Day.
Producer fires and ash sampling	Mr. Bibbins.
Computations and indicator cards	Messrs. Armistead, Bibbins and Day.

Norton Company	Messrs. Alden and Griffin.
Worcester Polytechnic Inst	Mr. D. L. Gallup.
Amer. Steel and Wire Co	Messrs. Hill, Bisson, Burke, Leland, Stevenson and Phelps.
Power and Mining Machinery Co	Mr. Von Sholly, chemist.
The Westinghouse Mch. Co	Messrs. Armistead, Bibbins, Chapman, Bradley, Dodge and Day.
W. E. & M. Co	Messrs. Fick and Mudgett.
General	Messrs. Keith, Johnson and Morden.

SOME LIMITATIONS OF THE MOLDING MACHINE

By E. H. MUMFORD, PHILADELPHIA, PA.
Member of the Society

The recorded art of molding by machinery is far older than that of the steam engine, and there lacked only to-day's demand for multiple parts and the facilities for developing the art to have put it where it is now a hundred years ago. Thus, just as soon as a stripping plate was needed, it was "invented"—*more* than a hundred years ago and as soon as a foundryman felt the vibration of a pneumatic hammer he used what we now call a "vibrator" to help draw a guided pattern.

2 About twenty years ago S. Jarvis Adams in Pittsburg jolt-rammed molds for pipe balls and wagon axle boxes; yet even today the modern jolt ramming machine at an exhibition attracts a crowd of foundrymen amazed at its novelty.

3 It was their long years of experience with the subtle and elusive behavior of green sand in the presence of melted metal in the secret intimacies of the closed mold that led Union molders some sad years since to scoff at molding machines and to foretell their doom unaided by the molder's skill. And molding machines have failed—machines of much ingenuity—heralded as labor savers because they did so many things done before by hand. These machines have failed because of too many opportunities for failure in a single enchained mechanism. Kipling's "Interdependence absolute" of McAndrew's

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idol engine is not for foundry use. Before the heartless biting cynicism of foundry ethics many a clever engineer has come to grief. Where melted iron rules and sand intrudes with every lubricant, refinements of machine design may not be much elaborated.

4 And so, though the Patent Office is filled with ingenious molding machines, most of them have failed as the molder prophesied while the art of machine molding has steadily progressed. It is still eliminating the machines which bring the sand in from the yard, temper it, riddle it and ram it, pass themselves their flasks, sand frames, sprue cutters and other accessories, draw their patterns, deliver the finished molds and have only to be restrained from setting the cores.

5 It is assimilating a good simple efficient machines content to do a few things well.

6 It is not speed of production of blocks of sand which look like molds and which in the halcyon days of "demonstrated" machines often passed as such and sold the machine even while the "demonstrator" walked around upon them which in 1907 proves the machine. The present day molding machine must take what the foundry gives it and turn back what the foundry wants,—molds in quantity and of quality excelling in economy of production, the product of hand labor in *castings* or it gets no welcome there.

7 But there is another reason for the markedly gradual and cautious development of the molding machine. It is the infinity of shapes and kinds of patterns around which green sand must be rammed with uniformity of mold surface, and the necessity of arranging some more or less universal method of withdrawing these patterns from the rammed sand without in the least degree displacing it.

8 In other fields it has paid the most brilliant mechanicians of the age to develop elaborate and expensive machines for doing one kind of work always. Our machines for making cigarrettes, envelopes and paper bags are fair examples. For molding machines there is no one casting of a certain size and shape in required quantity comparable with cigarettes, etc. At the speed of the envelope machine, a few molding machines would supply the demand of the entire country and in any one shop a single machine would run far ahead of its market in a day or a week or a month, and then waste its shop room.

9 Another limitation to the exploitation of molding machines to make molds as bricks are made lies in the fact that these machines, unlike those for making bricks, do not finish their work. Sand and flasks must be supplied to the machine and castings must be poured and cooled and shaken out. It would not be difficult to design a

machine which would mold for example, 200 shoes per hour, and such machines have, in fact, been built. Each machine, however, would call for 5000 pounds of sand and as many pounds of flasks to be delivered to it and carried away from it again every hour. Even then the molds are in halves and without cores set; 200 cores must be set and 100 copes closed on every hour. To keep the "floor" from gaining on the foundry, 5000 pounds of hot metal must be poured from double hand ladles every hour which work would keep from four to six men busy pouring and shifting weights. As many more men would be required to shake out and remove hot castings, and at least two more to get the flasks off of the floor again. Only a little foundry experience will prove that this situation is impossible. The elaborate foundry structures for dropping both sand and castings through the floor still leave the labor of setting cores, handling and closing molds, pouring and shaking out to be performed. In fact, we are far from the realization of a molding machine which will turn out castings, as do the type casting machines and all machines which cast mildly hot metal in chills, and which may not be called molding machines as their molds are already prepared. The mold which melted iron will not destroy and which will not exaggerate unequal cooling of the casting surface, with resulting evils, is no nearer our commercial use than is the Philosopher's Stone and, until it is, the molding machine, delivering only incomplete sand molds, will still invoke the genius of the designers who know where to limit its functions, and the ignorance of those who do not.

LIMITATIONS OF MACHINE FUNCTIONS

Ramming

SOFT DEEP SAND

9 Sand will flow only slightly under pressure, hence pressure and blow ramming machines fail to reach deep parts because shallower parts absorb the pressure.

10 Sand, especially in pressure ramming, is subjected to great friction in its movement down the sides of patterns and flasks—hence even directly vertical pressure over deep parts does not ram them down all the way.

RAM OFFS

11 After sand is partially set in a mold, by pressure or other means, it has taken the shape of the pattern, and if it is moved, it carries this

pattern shape—as of a corner—with it. Thus a blow of a hand rammer at one side of the sand, compressed by a previous blow, shifts that partially rammed sand aside, and generally away from the pattern.

12 In jolt-ramming machines a peculiar ram off effect occurs at every convex corner of a pattern. This is due to previous jolting having set the sand over the pattern at the corner, with the result that little of it can follow out and down past the corner to take the place of the deeper sand which the later blows of the jolting cause to settle down the more or less vertical sides of the pattern. The result is a zone of soft sand just under the pattern corner.

13 Still another failure in ramming, in the nature of a ram off, occurs in what is coming to be known as the "gravity" machine, though it is no more entitled to the term than the jolt-ramming type gravity alone being employed in both machines. Allusion has been made to the upward looking convex corner of the pattern around which it is hard to get the sand to flow. In the jolt-ramming machine the sand is placed in pockets, and the long pattern sides prior to ramming, while the sand in the "gravity" machine falling in bats, tends to shed off the corner more than sand previously placed around it; and this has led to constant failure in the past in this very old method of ramming. Moreover the sand, falling from a fixed height, tends to ram all parts of the mold equally hard—which has the especially undesirable effect of making copes as hard as drags. In fact it seems worth mentioning here that what is called "uniform ramming" is not a desirable feature in molding machines. The more sand density can be varied the better.

14 In vibrator frame machines, called such, though the same term may be applied to any machine using an undivided pattern with extensions from the patterns to guides outside the mold, the effect of ram-off is commonly produced by springing of the unsupported pattern during ramming—it being immaterial whether the movement be in the sand or the pattern.

BARRED FLASKS

15 Flask bars have been a limitation more or less serious in all molding machines. Taking all kinds of bars into consideration, including those which spring under jolt or pressure ramming, there are none which do not give trouble, or cause loss of time, if we except the so called "floating bars," and even these must be nicely proportioned to depth of sand, etc.

16 Pressure-ramming machines must employ special ramming blocks cut away to clear bars.

17 Jolt-ramming machines require that the bars shall be very thin, and yet not spring, for if a bar shakes off the contact of the sand and the frictional bond between the sand and the bar is destroyed, the bar merely aggravates the tendency of the sand to drop from the flask, by cutting it into channels and unsupported blocks.

18 The writer knows of only one bar that will hold the general mass of sand, after the sand has actually separated from its under edge. It is one which has been designed specially for jolt-ramming and tested with complete success and it permits the sand to settle away from it in the cope while keeping the mold from "coping," as the runner fills up; for it holds the sand down as well as up.

19 The floating bar, whose action is ideal, if its descent into the sand under it is properly controlled, is an element in what is known as bottom-ramming, and the action is the same whether the bar only, or the bar and the flask which holds it, moves toward the pattern in ramming.

20 This is the only form of flask bar which is not even theoretically, a limitation to ramming by machine.

RAMMING PATTERNS DOWN OR SAND UP

21 It is impossible to ram sand up into an inverted pattern, as is required in making a drag mold without rolling. The pattern must first be filled and surrounded with sand. Rathbone did this first in 1905. He was using a blow-ramming machine, with an inverted drag pattern on a match board for producing multiple molds, and found that the projection of the unrammed sand against the pattern an instant before ramming—a result incidental to the apparatus he used,—accomplished what had not been done before.

Machine Limitations in Pattern Drawing

MISMATCH

22 It is assumed that patterns and flask pins are accurately fitted; this match is caused by the following four conditions: *a* cope and drag parts of the pattern on separate carriers—nothing but a miracle can insure accurate match, for all the errors due to misfits of the dowels, etc., enter in, as they do not when the same rigid piece carries both parts; *b* the pattern carrier separated from the part of the machine containing the flask pins. An apparent exception to this

is the ordinary stripping plate machine, when patterns are new. In this case, the pattern may move out of match, but the new stripping plate with flasks pins in it, in sliding over them, forces them into place. It goes without saying that the edges of both the stripping plate and the pattern suffer in consequence. *c* Lack of support of joint surface during pattern drawing downward causes sagging of joint.

23 If from any cause the two point surfaces of a mold are not perfectly flat, or, if not flat, perfectly inversely similar, such a joint will "creep" out of match in closing. For this reason mainly better matched molds are obtained from stripping plates, which support the point during pattern drawing.

24 In the first use of vibrators on machines, the slight lateral freedom of the pattern carrier necessary with reference to the mold was secured by the proper freedom of a match plate on the flask pins. In the endeavor to improve vibrator action, the pattern carrier was separated from the part containing the flask pins. The idea was that the agitation and dropping of the sand while drawing patterns *down* would be thus avoided. While this was, in a measure, accomplished, the clearances thus introduced allowed the patterns to shift out of match during ramming, and led to the introduction of untrustworthy automatic locking devices dependent upon springs.

25*d* Bottom boards and match boards springing under ramming produce the amorphous joints last referred to by causing convex drag joints, if the ends of boards have sprung into molds, and concave drag joints if the centers have sprung in. A prolific source of this failure in machines is the use of skids instead of flat tables in pressure-ramming machines. For example, with 2½ inch skids, placed 10 inches apart, the center of the board of a mold 14 inches long will be sprung in, producing a concave drag joint; while the ends of the board of a mold, 28 inches long, will be sprung in and a convex drag joint result.

BROKEN CORNERS

26 Stripping plates know no such failures, for their essential function, as indicated by their French name "*peignes*"—combs, is to comb the sand along the edges of the pattern. But, in those machines which employ vibrators to start the edges of sand, three things are necessary: *a* Clean and well drafted edges of the patterns. *b* Absolutely straight movement of these edges relatively to the sand, or *vice versa*. *c* Flasks undistorted by clamping or otherwise.

27 In the matter of clean joint edges, an interesting detail has within the last few years been developed. Split patterns on match plates are frequently hollowed out to save weight and metal, and all

patterns have more or less air space between them and the plates. Mr. Walker, at Erie, found that at the moment of ramming by pressure, the air under the patterns is compressed to the 30 to 50 pounds pressure of the mold, and that, to effect this compression, the very damp air in the unrammed sand is forced under the pattern—then, immediately, when the pressure is taken off of the sand, this imprisoned damp air issues from this hollow under the edges of the patterns next to plate. This constant breathing in and out of wet air causes wet corners, to which the sand adheres.

28 This has led Mr. Walker to adopt the plan of sweating his patterns on a tinned plate. The little fillets of solder which run up along the pattern edges, help the pattern draft very materially.

29 The slightest touch of a pattern on the sand corner that is leaving takes at least a little of that corner with it. An illustration of this has been the absolute failure of what is known as the vibrator frame, and of vibrated solid patterns on chain link and saddlery hardware. The hand molder, rapping his pattern through the cope into the closed joint of his mold and then, with practised hand setting his patterns in the exact center of the enlarged sand chamber he has formed, lifts his cope clear and clean, while the vibrator moves the pattern very little. The guide on the flask pins, though true, is vitiated by the rocking in hand lifting, the sand corners are sure to touch somewhere, and just there the sand is either torn up or knocked down, depending upon whether the pattern is drawn up or down.

UNTRUE DRAFT

30 I have just mentioned the rocking of a mold or pattern by hand as fatal to clean draft. Any divergence from a line of draft normal to the joint surface of the mold, or a line predetermined, is equivalent to vitiating the "draft" given the pattern by its maker and setting up a back draft. Yet these conditions arise in what are known as rock-over machines, which draw their patterns from molds lying on tilting bottom boards.

FLASKS SPRUNG

31 Hand-rammed rock-over machines retain a weakness which every experienced molder would avoid. The flask—often a very shallow wooden flask— is edge-clamped to the pattern board. The springing and subsequent recovery of the flask deform the joint of the mold unless the hand molders' method of wedging the joint is adopted. Mr. Pridmore foresaw this difficulty when he first began to build rock-over machines years ago, and patented clamps which prevent the springing of the flask.

32 It is an axiom in machine molding that all pattern draft must be taken from the mold joint, and that this joint must be maintained without deformation until the mold is closed.

SIZES AND SHAPES OF MOLDS

33 Molding machines are now in a position to say to the trade that the mere size of a mold is no reason for not making it by machinery. This is very evident in the case of hand-ramming machines where the problem of furnishing from 15 to 100 pounds ramming pressure to every square inch of area is not encountered, and in the most widely known hand machines, where the ends of the frames which carry the stripping plates are left open, any length of flask within the width capacity of the machine may be accommodated, provided the length is not sufficient to cause too great an overhang.

34 Until this year, America has not known familiarly a complete molding machine that would handle for both ramming and drawing patterns any size or shape of mold for which it had ramming capacity. Consider for a moment what it has meant to the introduction of molding machines that a power machine has been used for, at most, three or four sizes of flasks, the only latitude being in width, and this limited to a narrow maximum.

35 In lathes, many diameters and lengths of work are handled. In planers, variations in all three dimensions are provided for. Yet, in molding machines, where the sizes of molds are as various as the sizes of the castings which go to a machine shop, designers in this country have contented themselves with practically a separate machine for each size of flask.

36 To illustrate how easily satisfied the foundry trade is, let me say that for years several machines of different sizes have been sold to foundries in which a single size, and often a single machine, would have answered the purpose.

37 And the only arguments advanced therefor have been: *a* It will not do to have too large a top on a machine, as the projection beyond the flask catches sand. *b* The flask pins in the machine require that the pin dimension of the flasks should be constant.

38 Our technical press has lately been filled with descriptions of a French molding machine and its equally interesting pattern equipment, which is without any question the most brilliant work in machine molding in a hundred years of development. The able Frenchmen who have evolved this mechanism have christened it "Universal," with an intensity of meaning characteristic of the deep thought which has produced it.

39 As to the machine itself, what has it done? It has emasculated the potent arguments which have filled our foundries with polyglot machines, since no part of the French machine projects beyond the flask to catch sand, no matter what the size or shape of the flask and the flask pins *are not in* the French machine.

40 It is not necessary here to describe this remarkable machine and its fit companions, the Plaques Modêles and Clichés Tables which promise to reduce our molding machine pattern costs from 50 to 90 per cent. Very complete descriptive matter from one of the inventors, Mr. Ronceray, has been published in the "American Machinist" and elsewhere, and later on, a full functional analysis of these machines may well add to the value of our Transactions.

41 The writer will enumerate the limitations of the molding machine as known in America to-day, which are eliminated by the new machine molding of France.

Ramming

SOFT DEEP SAND

42 All the French machines may be fitted at a trivial cost with *Double Serrage*—an appliance for double-ramming. This is simply an auxiliary plunger under the mold table of the machine, set quickly to stop gage, to which are attached what we call, in the United States "stools." While the main ramming pressure is on, these stools, which have receded to allow a given amount of sand to enter the pocket or cavity, are run against the stop gage and the soft sand is made just hard enough. This procedure is general from Tupper grate bars to deep and intricate green sand cores in automobile castings.

RAM OFFS

43 Only a single application of pressure is made, and deep vertical sides are rammed from the opposite direction so that no "ram-off" can occur.

MISMATCHED

44 As the flask pins are not in the machine,—though they are drawn by the machine,—the match is made and maintained in the foundry so that, with full responsibility, the foundry may also have credit for matches more perfect than heretofore.

BROKEN CORNERS

45 As stripping plate patterns made by the French process are as cheap as the various forms of vibrated patterns heretofore known in America, it becomes much more practicable to adopt stripping plates.

46 Broken corners, such as have to be considered in vibrated patterns, are unknown to stripping plates. In fact, except for the cost of the latter, there would never have been use for vibrators in connection with molding except as adjuncts to stripping plates. This is even true of patterns drawn *up*, especially, as in the inverting French machines, the stripping plates or stools follow the sand down automatically.

UNTRUE DRAFT

47 There can hardly be truer pattern draft than that guided by the same plunger which has done the ramming, as is the case in all the French machines of the rotary or inverting type. The only necessary precedent is that the ramming, or bottom board which has been forced into the flask, if such an one is used, shall have an even seat when the mold which is being lowered on the inverted ramming plunger is leaving the pattern. The slightest difficulty from this source is easily removed by three-point bearings.

48 In the French machines of the fixed type, the pattern draft datum is taken from the mold joint itself, inasmuch as the columns which raise the stripping plate and the half mold upon it have adjustable tops which are set at the start to conform to the exact surface of the mold.

FLASKS SPRUNG

49 Since no clamps are used, there can be no springing of flasks from this cause. Furthermore, I would here mention an innovation illustrating the national differences in everyday practice in the molding methods of two countries, in even these latter days of constant interchange of ideas.

50 The French use round flasks as commonly as we do square ones. They use snap flasks hardly at all, and yet they obtain from solid flasks what we know only as snap molds.

51 When it is stated that 220, 21-inch round "snap" molds are produced in a day by two men from "solid" flasks, I know that many will ask "How?"

52 The molds are made as molds in 21-inch round flasks would ordinarily be made; except that very thin "binders," hoops of steel

only $\frac{1}{32}$ inch thick, are employed. The drag mold is then set upon a plate on the round table carried by an assembling machine, the table and plate being a little smaller than the inside of the flask. This plate serves as a bottom board. The cope mold is placed above the drag, over long pins common to both parts, so that the match is absolute. The cope flask being locked so that it cannot rise, the plunger rising against the drag carries it up to the cope, closing the joint, and then the continued ascent of the plunger forces the sand bodily up out of both flasks, and we have the strongest shape possible of a snap mold held by binders—a cylindrical one.

53 Thus by methods radically new we are introduced to a system of machine molding which has profited by a study of the limitations of previous machines. Not all of the limitations I have named nor others not mentioned, because so numerous, have yet been surmounted; but Paris at present holds the prize for the greatest advance.

54 So complicated and so varied are the demands upon the foundry molding machines, that, unattractive as the hot, dusty foundry is to engineers, I suggest that to-day there is no more promising realm of thought to attract the genius of the machine designer who has had the opportunity to learn by hard experience what a molding machine can, and what it absolutely cannot do.